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GEOLOGICAL SURVEY

OF

ALABAMA.

BULLETIN No. 6.

PRELIMINARY REPORT

ON THE

CLAYS OF ALABAMA.

DUPLICA
TO BE K

Evening Post

GEOLOGICAL SURVEY
OF
ALABAMA,

EUGENE ALLEN SMITH, Ph. D., State Geologist.

BULLETIN No. 6.

PRELIMINARY REPORT
ON THE
CLAYS OF ALABAMA,

BY

HEINRICH RIES, Ph. D.

THE VANCE PRINTING CO., STATE PRINTERS AND BINDERS,
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1900.

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To His Excellency,
JOSEPH F. JOHNSTON,
Governor of Alabama.

DEAR SIR:—I have the honor to submit herewith, as part of my biennial report, 1898-9, a report upon the clays of Alabama by Dr. Heinrich Ries. While the investigations of Dr. Ries here recorded have been confined to the northern half of the State, and mainly to one or two formations, they yet embrace the most important and most accessible of our clay deposits. The kaolins of the granite region lie at a distance from railroad lines, and the discussion of these and of the clays of the more recent formations, in the lower half of the State, will be taken up in a second bulletin.

The present report shows that our clay resources include every variety, ranging from the best of china clays downward, and there seems to be no good reason why all these materials should not be turned into the manufactured products, chinaware, stoneware, fire brick, ornamental brick, paving brick, tiles, drain pipes, etc., within our own borders and upon our own ground.

Very Respectfully,
EUGENE A. SMITH.

University of Alabama,
March 15, 1900.

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PREFACE.

Clay is one of the most abundant materials found in the earth's crust, and occurring as it does in every country, in almost every geological formation from nearly the oldest to the youngest, and frequently in positions easy of access, it is not to be wondered at that these conditions, aided by the peculiar properties which it possesses, have caused this material to become one of the most useful and valuable products of the earth.

The value of clay is still more readily understood when the statistics of its production are known. Thus in 1897, the total value of clay products made in the United States alone was $60,911,641.00, distributed as follows:

Common brick	$ 26,353,904
Pressed brick	3,931,336
Vitrified paving brick	3,582,037
Ornamental brick	685,048
Fire brick	4,094,704
Drain tile	2,623,305
Sewer pipe	4,069,534
Terra cotta	1,701,422
Fire proofing	1,979,259
Tile other than drain	1,026,398
Miscellaneous	1,413,835
Pottery	9,450,859

Up to the present time the rank of Alabama as a clay producing state has not been very high, owing largely to the lack of information concerning its clay resources, and in the following report an endeavor has been made to furnish as much information as possible concerning the characters of many of the Alabama clays.

HEINRICH RIES.

March 1, 1900.

I

GENERAL DISCUSSION OF CLAYS,

BY HEINRICH RIES.

ORIGIN OF CLAY.

Clay is to be met almost every where, and while it varies in form, color and other physicial properties, nevertheless it always forms a pasty or plastic mass when mixed with water, by virtue of which it may be molded into any shape, which it retains when dried; furthermore when exposed to a high temperature it hardens to a rock like mass. These two properties, the plasticity and the hardening when burnt are what make clay of such inestimable value to man.

Pure clay or kaolin is composed entirely of the mineral kaolinite, which is a hydrated silicate of alumina. It rarely happens, however, that clay is perfectly pure, for owing to the nature of its formation from another rock as will be explained later, it is very apt to have other minerals mixed in with it. These foreign minerals may sometimes be present in such quantities as to completely mask the character of the kaolinite.

We can therefore define clay as a mixture of kaolinite with more or less quartz and other mineral fragments, especially feldspar and mica, the whole possessing plasticity when mixed with water, and becoming hard when burned.

The so called flint clays form an exception to the above, for while they often approach pure kaolin in composition, still they are almost devoid of plasticity when ground and mixed with water.

Kaolinite is a secondary mineral resulting from the decomposition of feldspar. The feldspars are a group of silicate minerals of rather complex composition, with orthoclase, the potash feldspar, serving as the type of the group, as well as being the commonest species.

Under the influence of chemical action, which may be the result of weathering or in some cases probably of acid vapors ascendning from the interior of the earth, the feldspar becomes decomposed, and the result of this is that the potash of the feldspar is removed partly in the form of solube carbonate, or perhaps silicate, or even fluoride, while the alumina and silica remain and unite with water to form the hydrated silicate of alumina, kaolinite, whose composition is expressed by the formula $Al_2 O_3, 2SlO_2, 2H_2O.$, or in the proportion of silica, 47.30 per cent.; alumina, 39.80 per cent.; water 13.90 per cent.

The change can be illustrated still better by the following in which the first column indicates the composition of the feldspar, the second the amount of water taken up in the process of decomposition, the third, the amount of matter removed in solution, and the fourth the relative amounts of the three ingredients of kaolinite.

	Feldspar.	Added.	Dissolved out.	Kaolinite.
Alumina....	18.3	....	0.0	18.3
Silica....	64.8	....	41.8	23.0
Potash....	16.9	....	16.9	....
Water.....	....	6.4	....	6.4

Many clays approach quite closely to kaolinite in their composition, and in some the percentage of alumina even exceeds the theoretic amount, by one or two per cent., and is evidently not due to errors of analysis.

It has been suggested by some that this may be due to the presence of a certain amount of *pholerite*, the amorphous variety of kaolin,* and while this is possible the same composition might be shown by a certain amount of bauxite or alumina hydrate mixed in with the clay.

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* Wheeler, Clays of Missouri, Missouri Geological Survey, XI.

None of the Alabama clays thus far analyzed indicate this exceptional composition.

Knowing the mode of origin of kaolinite it will at once be seen that the purity of the kaolin depends on the nature of the parent rock. Feldspar often forms large veins of considerable purity, and nearly free from other associated minerals, and its decomposition in such cases would give rise to deposits of pure or nearly pure kaolin. In point of fact the purest clays known have with few exceptions been formed in this manner. More frequently quartz and mica are common accessory minerals, and remain intermixed with the kaolinite, both of them being more resistent to weathering than the feldspar. When these or other minerals occur in the kaolin they have to be separated from it as much as possible by washing.

Clays, which occur at or close to the locality in which they have been formed, are called "residual clays". They represent some of the purest types of clay known as well as the most impure. The upland region of the Southern States is underlain by a great area of feldspathic, granitic and gneissic rocks which have decomposed to a ferruginous clay of residual nature, and one that is used extensively in the South for the manufacture of common brick.

In the general wearing down of the land surface which is continually taking place the particles of residual clay are washed down into the lakes and oceans and deposited there as sediments, thus giving rise to what are known as sedimentary clays. They are usually far more plastic than the residual clays, especially the purer ones.

From the nature of their formation, we should seldom look for kaolins of sedimentary origin, and when they do occur they have probably been derived from large areas of very feldspathic rock or possibly from limestones which had an appreciable percentage of silicate of alumina in their composition, in which case the lime carborate would be carried off in solution, and the clay components of the rock be left behind as an insoluble residue. It is seldom that sedimentary clays exhibit such remarkale purity as those from Chalk Bluff, Alabama, or the plastic ball clays of Florida.

The clays of the Cretaceous and Tertiary formations, which underlie the Coastal Plain, as well as the Palaeozoic shales found in Alabama, are all of sedimentary origin.

GEOLOGICAL STRUCTURE AND DISTRIBUTION OF CLAY DEPOSITS.

RESIDUAL CLAYS.

The mode of origin of these has already been explained. They may occur either in the form of a broad mantle overlying the bed rock and showing a variable thickness as well as extent, or they may occupy the position of a vein cutting across the strike of the other rocks, or extending at times with the bedding or lamination of them.

Residual clays are commonly made up of a mixture of angular grains which are chiefly undecomposed mineral matter, and clay particles which are mostly of sufficient fineness to remain suspended in water for an almost indefinite period. There is also generally a gradual transition from the fully formed clay at the surface to the fresh rock below, whose decomposition has given rise to the plastic mass above.

The depth below the surface at which the unaltered rock is encountered may be as little as three to four feet, while in some regions where the surface has been little eroded, and decomposition has been active, the thickness of the residual clay may exceed one hundred feet.

The structure of the parent rock such as stratification or lamination is at times often noticeable in the lower portion of the residual deposits, and in some cases it may even be preserved right up to the surface.

Residual deposits of the vein type result commonly from the decomposition of veins of granite or feldspar. They vary in width, from a few inches to several hundred feet, and their vertical extent depends in most cases on the depth to which the weathering action has progressed.

Veins of kaolin seldom show great length, and when followed along the surface not uncommonly pinch out in both directions. They are often separated more or less sharply from the country rock, and this distinct line of demarkation is preserved even when the wall rock itself is decomposed. They furthermore frequently branch and at times contain lenses of quartz, which resist the weathering agencies and stand out in bold relief on the surface. It rarely pays to work a vein under six feet in width.

Deposits of kaolin of the type just described should not be confused with sedimentary deposits of white clay, which are usually of a much greater extent than the vein formation.

SEDIMENTARY CLAYS.

These occur in the form of beds, which are either close to the surface or interstratified with other deposits which have been accumulated in water, such as sandstone or limestone. They are not unfrequently interbedded with coal deposits and many a coal seam has a fire clay floor. Sedimentary clays are, as a rule more homeogeneous than residual ones, and contain probably a greater portion of fine particles. They are also more plastic, and frequently contain much disseminated organic matter. Furthermore, they do not pass gradually into the underlying rock as residual clays do, and indeed bear no relation, in a genetic sense, to the rocks upon which they rest.

When sedimentary clays become compressed by the weight of overlying sediments, they assume the character of hard or consolidated rock, and are known as shale. Shales therefore simply represent the finest clay sediment which has bcome consolidated.

On grinding to a powder and mixing with water, shales become just as plastic as other clays. By mentamorphism, (that is heat and pressure developed by mountain making processes) taking place in the crust of the earth, a shale may lose its chemically combined water, develop a cleavage, and become converted into slate. It is then no longer possible to develop any plasticity in the material.

It is not to be understood that all sedimentary clays are of a homogeneous structure throughout. Some beds may exhibit a wonderful similarity of composition throughout extended areas, while again there may be a wide variation in the character of any bed within narrow limits. Apart from this variation laterally, there may also be a vertical one in cases where the deposit is made up of a number of beds, one over the other, each showing distinctive characters. With such occurrences it is possible to obtain several different grades of clay from the same pit. Such conditions are apt to be the rule rather than the exception.

A not uncommon phenomon in many of the coastal plain formations is the occurrence of large lenses of clay, free from grit surrounded by beds of sandy clay or even sand.

DISTRIBUTION.

Clays and shales occur in practically every geological formation with the exception of the oldest. Most of those which are older than the Createceous are hard and shale—like in their nature, while those of the Cretaceous and Tertiary on the other hand are usually soft and plastic, but deposits of Createceous and also Tertiary shales are known.

The geological age of a clay or shale is no indication of its quality, and it is only of use at times for a means of comparison between two beds situated near each other, but even here it is not altogether a safe guide.

The geological relations of the clays of Alabama are treated somewhat more in detail below in a separate chapter.

PROPERTIES OF CLAYS.

These fall into two classes, i. e. (1) Chemical and (2) Physical. Two clays may correspond in their widely in their physical characters, and therefore act entirely opposite when used for the manufacture of clay products.

Pure clay or *kaolin* would be composed entirely of *kaolinite*, the hydrated cilicate of alumina. These two terms are often confounded and it is well to empahasize the fact that kaolinite refers to the mineral species, while the term kaolin is applied to the mass. Pure kaolin has not thus far been found, although deposits containing as much as 98 per cent. of it are known, and the other two per cent. consists of foreign matter. The kaolin therefore contains a variable amount of mineral impurities mixed in with the kaolinite or the clay substance, as it is some times called, and these impurities may affect both the chemical and the physical properties to a variable extent, depending upon the quantity and the kind of them present. The clay substance is always present but in a variable amount, and it stands in no direct relation to the plasticity, except in so far that the latter is lost when the combined water is driven off.

The amount of clay substance in clays ranges from 5 or 10 per cent. to 98.5 per cent.

The chief impurities in kaolin are quartz, feldspar and mica, but in other clays the number of mineral species present may indeed be large.

CHEMICAL PROPERTIES.

The chemical composition of a clay directly influences its fusibility, and the color to which it burns.

The compounds which may be found in clay are silica, alumina, iron oxide, lime, magnesia, potash, soda, sulphuric acid, phosphoric acid, manganese oxide and organic matter. Compounds of chromium and vanadium may also be present at times in small amounts. All of these substances are not present in every clay, but most of them are.

Pure clay would contain silica, alumina and combined water, but the purest clay known commonly contain at least traces of iron oxide, lime and alkalies.

Alumina, organic matter and water are practically the only non-volatile constituents, which do not exert a fluxing action on the clay in burning, and the intensity of this fluxing depends partly on the amount of fluxes, and partly on the temperature at which the clay is burned.

It is the custom to divide the impurities of clay into those which are fluxing, and those which are non-fluxing.

Pure clay is very refractory. The kaolinite composing it contains two molecules of silica and one molecule of alumina. A higher percentage of silica tends to increase the fusibility up to a certain point, provided it is in a finely divided condition. above this point the refractoriness of the clay increases steadily with the addition of silica.

Other substances are far more powerful fluxes than the silica however, and these fluxes contain not only elements but also definite chemical compounds or mineral species.

The influence of fluxes increases not only with the amount present but also with the state of division, they being more active, the more finely they are divided. If the fluxing material is present in large grains, these will only exert a fluxing action on their upper surface, while the single grains alone will for a while act more like quartz grains i. e. as diluents of the shrinkage. The minerals which may be present and serve as fusible impurities are commonly mica, feldspar, hornblende, pyroxene, garnet, quartz, calcite, gypsum, iron oxide and manganese, and the elements contained in these constituting the active fluxing agents are alkalies, iron oxide, lime and magnesia.

Opinions differ somewhat in regard to the order of their relative effectiveness, but it is probably given above, the alkalies being the strongest.

The amount and kind of fluxes which it is desirable for a clay to contain depends on the use to which it is to be put. If a vitrified ware is desired then the fluxes should be present in appreciable amount, say 10 to 20 per cent., depending upon the relativestrength of the fluxing impurity. Refractory clays, on the other hand, should contain a low amount of fusible substances. Porcelain clays might have as high a percentage of fluxes as 5 or 6 per cent., provided they did not exert a coloring action on the clay.

ALKALIES IN CLAYS.

The alkalies usually contained in clays are potash, soda and ammonia.

Ammonia is a very common constituent of moist clay and is absorbed by the latter with great avidity; indeed it is largely responsible for the characteristic oder of clay.*

If the ammonia remained in the clay, it would act as a strong flux, but its volatile nature renders it harmless, for it passes off as a vapour at a temperature considerably below dull redness, and in fact may even volitilize with the moisture of the clay during the early stages of burning.

Potash and soda on the other hand, which volatilize only at a high temperature, are present in almost every clay from the smallest amount up to 9 or 10 per cent. and of these potash is by far the commoner of the two. Their variable percentage may be caused by the presence of more or less undecomposed feldspar, of which orthoclase, the common species, has nearly 17 per cent. of potash while the other feldspars contain varying amounts of soda.

These alkalies may be present in the clay in the form of either soluble or insoluble compounds, the latter being represented by feldspar, mica, or other minerals, while the soluble ones are usually the result of their decomposition.

Soluble alkaline compounds may be found in almost any clay, but they are rarely present in large amounts, and their chief importance lies in the fact that they are often responsible for the formation of an efflorescence or white coating on the surface of the ware, they having become concentrated on the surface by the

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*F. Senft, Die Thon Substanzen, p. 29.

evaporation of the moisture of the clay. They may be rendered insoluble by the addition of chemicals to the clay. In addition to its unsightliness the efflorescence may interfere with the adhesion of a glaze applied to the surface of the ware.

Soluble alkaline sulphates are powerful fluxes and they also cause blistering of the ware, if the clay is heated sufficiently high to decompose the compound and permit the escape of sulphuric acid gases.

In some clays containing sulphate of iron, this compound may be decomposed by chemical reaction taking place in the clay; the sulphuric acid, which is thus set free, is apt to attack the alumina of the clay substance and if potash, soda, or ammonia is present there is formed an alum of potash, soda or ammonia, which can often be detected by the taste which it imparts to the clay.

Insoluble alkaline compounds. Feldspar and mica which are the commonest of rock forming minerals are the two important sources of insoluble alkaline salts in the clay.

The feldspars are complex silicates of alumina and potash, or alumina, lime and soda. Orthoclase is the only species furnishing potash and contains about 17 per cent. of it while the lime-soda feldspars have from 4 to 14 per cent. of soda depending on the species.

Orthoclase is the common feldspar, and next to it come albite and oligoclase with 12 and 14 per cent. of soda respectively.

The micas are complex silicates of alumina with either lime or magnesia or potash. Muscovite, the common species, contains nearly 12 per cent. of potash, and may at times also contain soda. While the potash feldspar fuses completely at about 2300° Fahr., the potash mica alone is very refractory and unaffected by a temperature of 2550° Fahr., and though it probably serves as a flux, it is not definitely known at just what temperature its action begins.

The alkaline silicates on account of their fluxing properties are frequently at an advantage, especially if in the form of feldspar, as they serve in burning to bring the particles of the clay together into the dense hard body, and also permit of the ware being burned at a lower temperature. If present in kaolins to the extent of several per cent. it is no detriment, provided no iron is present; an excess of feldspar, however, when added to a white burning clay will tend to produce a creamy tint.

In the manufacture of porcelain, white earthen ware, encaustic tiles and other products made from kaolins or white burning clays, and having a white body, which is impervious, or nearly so, the alkalies for the fluxing of this body are added in the form of feldspar.

Much feldspar is mined in this country for potters use, but all of it is the ortholase or potash feldspar.

IRON COMPOUNDS IN CLAYS.

Iron is not simply a fluxing impurity, but it is also the great coloring agent of clays in either their burned or unburned condition, and furthermore when in the form of the hydrated oxide or limonite it may serve to increase the absorbtive power of clay. *

The compounds in which iron may exist in the clays are as follows: Oxides:—limonite, hematite, magnetite, ilmenite. Silicates:—mica, hornblende, garnet, etc. Sulphides:—pyrite and marcasite. Sulphate:—melanterite. Carbonate:—siderite.

The iron oxides, limonite and hematite, are present in all clays, and may be introduced by percolating waters or be set free by the deccomposition of any of the iron-bearing silicates which the clay may contain. Not infrequently they are distributed through the clay in a very finely divided condition, or may form a thin film around the other mineral grains. Limonite tends to color the clay (unburned) brown or yellow, while hematite imparts a red color to it, and carbonate of iron may give gray tints.

The more sandy the clay the less the amount of the

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* A. E. Smith, Alabama Geological Survey, Agricultural Report, p. 45.

limonite required to produce any given intensity of color.

Mica is found in most clays, and hornblende and garnet are probably wanting in few, while the pyrite is often present in many clays, especially in stoneware and fire clays, its yellow, glittering, metallic particles being easily recognizable. When large, the lumps of pyrite can be extracted by hand-picking, but if very small, they can only be separated by washing. Under weathering influences the pyrite changes to sulphate of iron. In all of the iron-bearing minerals the iron is present in either the ferrous or the ferric stage of oxidization, and the fusibility of the clay is influenced somewhat by this fact, for ferrous compounds are more easily fusible than ferric ones. In the burning of the clay the ferrous salt will be converted into the ferric state, provided the action of the fire is oxidizing. But if it is reducing the clay will fuse at a lower temperature.

The action of weathering agent in nature is often sufficient to oxidize the iron in clays so that more ferric than ferrous iron will be found in most of them. This change is often noticeable in many clay banks where the upper, and at times more porous layers, are colored red or yellow, while the lower layers are blue or bluish gray.

It should be noticed, however, that a gray color may be produced by the presencce of organic matter, and the same material present in a dense clay, to which the air can not get access, may serve to retard the oxidation of the iron. Whenever iron exists in clay in combination with silica it is present probably as a complex silicate, for pure ferric silicate is very rare in nature.

Ferric hydrate increases the absorbing power of clay for both gases and liquids, but it as well as the carbonate change to the oxide in burning.

The general tendency in burning is to convert the iron compounds into ferric oxides, provided a certain temperature, depending on the fusibility of the clay, is not exceeded, for in every clay the iron seems to return to the ferrous condition as the point of vitrification is approached. This change is accompanied by a liberation of oxygen, which is responsible for the active swelling and blistering of the clay, which takes place as the point of viscosity is approached.

If treated to an oxidizing fire, the presence of ferrous salts in clay may not be considered, provided the heat is raised high enough to oxidize them, but the rapidity with which the temperature is raised is important, for when the heat is increased rapidly the outer portion of the clay tends to shrink and become dense before the air has had time to enter and oxidize the iron in the center of the clay body, the latter remaining in ferrous state. This is the cause of black cores sometimes seen in bricks whose exterior is red.

Unburned clay may be yellow, blue, brown, red or gray in color, depending on the relative amount of ferrous and ferric salts present, for iron is the one element above all others which by itslf colors clays.

The same variety of shades and colors may be produced in burning. Ferrous oxide alone produces a green color when burned while ferric oxide alone may give red or purple, and mixtures of the two may produce yellow, cherry red, violet, blue and black.*

Segar found that combinations of ferric oxide with silica had a red or yellow color§ while similar compounds of the ferrous salts showed blue or green.

The color to which any given clay burns may also depend on the intensity of the firing. Thus with moderate burning the iron may color a clay yellow or yellowish red, with harder firing this will pass into deep red, and on still more intense heating to blue or black, this latter color is to be seen on breaking open the arch brick in many kilns, but the surface of these same brick may also get black, due to ashes and cinders from the fire sticking to them.

The amount of ferric oxide permissible or desirable depends on the use to which the clay is to be put.

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*Keramik, p. 256.

§Notizblatt, 1874, p. 16.

The clays which are used for making white ware should not contain over one per cent. ferric oxide. And those with even three-quarters of one per cent. are apt to burn grayish at a high temperature, such as 2700 deg. Fahr. It is true that the reddish coloration of a small percentage of iron would be neutralized if any excess of carbonate of lime were present, but in this case even we should not get a pure white tint, but a yellowish one.

Brick clays should contain sufficient iron oxide to give a good red color to the ware when burned.

The bleaching of the iron coloration by the presence of lime will be mentioned later, an excess of alumina also tends to exert a decolorizing action upon the iron contained in the clay.

LIME IN CLAYS.

Lime is a most wide-spread constituent of clays, and occurs either in a finely divided state or else in the form of pebbles. An excess of lime in the clay in the former condition causes it to pass into marl, and in certain regions such clays are extremely abundant.

Lme may occur in clays either as a constituent of *silicate* minerals such as feldspar; in the form of *carbonate* as exampled by calcite or dolomite; or thirdly it may be present as a *sulphate*, which is the mineral gypsum.

The first two classes of compounds include minerals which are primary constituents of the clay, but the third type, gypsum, is usually of secondary origin, being the result of chemical processes, which took place in the clay mass.

The condition of lime is important, for in one case, it may be desirable, and in another it may do injury.

The presence of lime as a constituent of some silicate mineral is not infrequent, especially if the clay has been derived wholly or in part from crystalline rocks, such as gneisses and granites. The common feldspar, orthoclase, contains no lime, but the other species of feldspar do, and in addition there are other lime bearing silicates which are apt to be met with in most of the impure clays.

When present as a silicate, lime acts as a flux, and is less liable to exert a decolorizing action on the clay than carbonate of lime. Bleaching action is caused by the formation of a double silicate of iron and lime, when the clay reaches a temperature approaching vitrification, and the color developed is either yellow, or yellowish green, according to the intensity of the firing.

Carborate of lime is an abundant constituent of some clays, and its presence, if over three or four per cent., can usually be detected by the effervescence which is producd when muriatic acid is poured on the clay. This compound of lime is far more injurious than the silicate, although, if present in the clay, in a finely divided condition, it may not only be harmless but even desirable, provided there is not an excess of it, for clays with as much as twenty to twenty-five per cent. of lime carbonate have been used for making common or even pressed brick and somtimes earthenware. It is well, however, to try and keep the amount lower than this if possible. Highly calcareous clays have often found a use in making of slip glazes.

If the carbonate of lime is present in the form of pebbles, a most undesirable effect is produced, for it is well known that when heated to redness, the compound is broken up into oxide of lime and carbonic acid gas; this oxide of lime, when cooled, absorbs moisture from the atmosphere and slakes, the result being a swelling of the material and a consequent splitting of the brick. Now if the clay be heated to a temperature sufficent to decompose the carbonate of lime, but not high enough to make it unite with any free silica present, the lime of course slakes on cooling. It is consequently imporatnt either to burn the clay sufficently or remove the lime pebbles from the clay by screening or by some other method before using.

For a high grade ware, calcareous clays are seldom employed, but in the manufacture of brick and terra-cotta, they are frequently utilized either because no others are available or to obtain a buff colored ware.

Some soft body porcelains have an appreciable amount of lime, much of the Hungarian containing from five to fifteen per cent. of CaO.[*] The bone china made in England at the present day also contains lime and some white earthen ware manufacturers use lime instead of feldspar.

Much buff ware is now made from semirefractory clays, which, on account of their low percentage of iron, burn to a creamy color.

The one objection to highly calcaeous clays is that the points of incipient fusion and vitrification (see Fusibility of Clays) lie so close together that it is not safe to burn them hard without running the risk of fusing them. Experiments have shown however, that it is possible to separate these two points, by the addition of quartz and feldspar to the clay, of sand containing a large percentage of these two minerals.

In addtion to lowering the fusibility of clay, lime also affects the fusion and absorptive power, thus Segar found[§§] that limy or marly clays required usually only twenty to twenty-four of water to convert them from a dry condition to a workable mass, whereas other clays needed twenty-eight to thirty per cent. of water to accomplish the same result. In burning the calcareous clays have not only their combined water to lose, but also the carbonic acid gas, and consequently the bricks are more apt to be light and porous unless they can be burned to vitrification. The shrinkage of calcareous clays is also less than that of others, and it sometimes happens that this shrinkage is not only zero, but that the brick even swells.

Many clays contain lime in the form of gypsum, the hydrated sulphate of lime. It generally results from the action, on carbonate of lime, of sulphuric acid set free by the oxidation and leaching of pyrite in the clay.

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[*] Sprechsaal, 1896, p. 2.

[§] Hecht, Thonindustrie Zietung.

[§§] Thonindustrie Zietung, 1877, p. 131.

When in large amounts, gypsum discloses its presence by the formation of transparent crystals or crystallne masses, whose surface shows a pearly lustre; at other times it forms as parallel fibres which fill cavities or cracks in the clay. Gypsum may prove to be a very injurious impurity even when in small amounts, especially if the clay is not burned to vitrification.

In the first place it serves as a fluxing impurity, secondly, it is dissociated at high temperatures, and the escape of the sulphuric acid causes blistering of the ware, and thirdly, although nearly insoluble in water, nevertheless small amount of it may be brought to the surface of the ware in solution by the evaporation of water and there left in the form of a white coating.

Kaolins commonly have very little lime, but in many common brick and stone ware clays, it frequently ranges from one to three per cent.

MAGNESIA IN CLAYS.

Magnesia is a constituent of many minerals, and yet it seldom occurs in large quantities, the amount in most of them rarely exceeding two per cent.

It may occur in the same classes of compound as lime i. e. *silicates,* such as mica, chlorite, hornblende and pyroxené; in *carbonates,* such as dolomite and magnesite; and in *sulphates,* such as epsom salts.

The silicates are, no doubt, the most important source of magnesia, for mica, chlorite, and hornblende are all common constituents of the more impure clays. They are scaly minerals of complex composition and contain from 1 to 25 per cent. of magnesia. The mica is frequently to be noticed in the sandy seams of the clay, while the other portions of the deposit may be quite free from it. Hornblende and pyroxene are to be looked for mostly in clays derived from the dark colored igneous rocks, and indeed the two latter minerals not only furnish magnesia, but by their decomposition furnish also iron oxide to the clay.

Dolomite, the double carbonate of lime and magnesia, may be present in some clays derived from magnesian limestone, while the sulphate of magnesia or epsom salts when present, may aid in the formation of a white coating on the surface of the ware; its presence can sometimes be detected by the bitter taste which it imparts to the clay.

The effects of magnesia in clays are considered to be the same as those produced by lime.

SILICA IN CLAYS.

Three types of silica may be recognized in clay, i. e.

1st. Quartz.

2nd. That which is combined with alumina and water in kaolinite.

3rd. That which is combined with one or more bases, forming silicate minerals, such as feldspar, mica, etc.

In chemical analysis the first and third are sometimes grouped together under the name of sand, or at times erroneously spoken of as free silica.

The sand is practically insoluble in sulphuric acid and caustic soda and this fact is utilized in the rational analysis of clay.

Few clays, so far as known, are free from quartz, but it is present in variable amounts in different ones. A minimum of .2 of one per cent. has been recorded from New Jersey* while the average in the Woodbridge fire clays is five per cent.

In the Missouri flint clays, a minimum of .5 of one per cent., is recorded, while the sand percentage is 20 to 43 per cent. in the St. Louis fire clays, and 20 to 50 per cent. in the Loess clays.§

27 samples of Alabama clays contained from 5 to 50 per cent. of insoluble residue.

70 North Carolina clays had from 15.75 per cent. to 70.43 per cent. of insoluble residue.

In European clays similar variations are observable. The most important effect of silica or sand is

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*G. H. Cook, Clays of New Jersey, 1878, p. 273.

§ Wheeler, Missouri Geological Survey, XI, page 54.

that as it increases the plasticity, tensile strength, and air shrinkage tend to decrease. In fact silica especially if present abundantly in large grains, may cause an expansion of the clay in burning.

Quartz serves as a flux at very high temperatures, but at lower ones it tends to increase the refractoriness of the clay, and this property is governed some what by the size of the quartz grains and the amount of fluxing material which will fuse at lower temperatures.

Sand acts as a diluent of the shrinkage in air drying and also in burning up to a certain point depending upon the fusiblity of the constituent grain.

In the burning of low grade clay, the quartz grains tend to act as a skeleton and preserve the form of the mass, while the fluxing impurity by their fusion bind the whole together.

TITANIC ACID IN CLAYS.

Titanium generally occurs in clays in the form of the mineral rutile (titanic oxide). It has always been looked upon as a rare element and a non-detrimental impurity, but the idea of its rarity has probably resulted from the fact that it is not commonly determined or looked for in the ordinary quantitative analysis. Its effect on the fusibility of clay has never been thoroughly understood, although it has seemed probable that its action was somewhat analogous to that of silica.

The experiments of Seger have indicated that when a hundred parts of kaolin and 6.65 per cent. titanic oxide were heated to above melting point of wrought iron, the resulting mass was densely sintered, and showed a dark blue fracture.

13.3 per cent. added to a hundred parts of kaolin gave a deep blue enamel at the same temperature, while an equal amount of kaolin with the addition of 10 per cent. of silica burned to a snow white mass at the same temperature and did not fuse. From this it will be seen that the actions of titanium and silica at high temperatures are not exactly alike.

ORGANIC MATTER IN CLAYS.

Organic matter affects not only the color of clay but also its plasticity, absorptive power and tensile strength.

It is present in clays either in the form of finely divided pieces of plant tissue or larger fragments of stems or leaves, which settled in the clay during its deposition, and have since become wholly or partly converted into lignite. All surface clays contain plant roots, but these exert little effect other than to aid the percolation of surface waters.

Clays colored by organic matter and containing no iron, burn white, as the plant tissue burns off at bright redness; if such a clay, however be heated too quickly, the surface of it becomes dense before all of the organic matter has had opportunity to escape from the interior, and the latter remains dark colored.

Organic matter may also mask the presence of iron so that the clay, instead of burning white, will burn red at a temperature of above that at which the organic matter passes off, below that temperature the vegetable matter will tend to keep the iron reduced. The clay from Fernbank, Lamar County, Alabama, contains 6.40 per cent of ferric oxide, and 2 to 2½ per cent of organic matter, but in the raw material, the latter hides the former. Organic matter exercises an important influence on the plasticity, often increasing it to an enormous degree, it also tends to elevate the tensile strength, the clay just mentioned showing 185 pounds per square inch, but high plasticity does not always indicate the presence of much organic material.

In the weathering of clays organic matter by its slow oxidation, aids in breaking them up by the escape of the carbonic acid gas.

WATER IN CLAYS.

All clays contain two kinds of water:—

1st. Hygroscopic water or moisture (mechanically absorbed).

2nd. Chemically combined water.

The *moisture* in air dried clays may be as low as .5 per cent. and reach 30 to 40 per cent. in those freshly taken from the bank. In the air dried specimens in the Alabama samples tested, it varied from .12 per cent. to 3.4 per cent.

In air drying most of the moisture is expelled, and this is accompanied by a shrinkage of the clay, which, in the case of the Alabama samples, was usually from 2 to 7 per cent., but in one case it reached 14 per cent.

The air-shrinkage of the clay ceases however before all the moisture passes off, the reason for this being that the shrinkage ceases when the clay particles have come in contact with each other, but there may still remain spaces between them which hold the water by capillarity, and the brick will contiue to lose weight but not in size, until all of this water has been driven off.

In practice it is this latter portion of the moisture that evaporates during the first period of the burning known as water smoking.

The air shrinkage of a clay varies with the nature of the material. Sandy clays usually show the least shrinkage, and of this kind the coarse grained ones diminish the least in size, while highly plastic clays usually show a high contraction in volume.

The amount of water, which a dry clay needs to develop its maxium plasticity is a variable quantity. Plastic clays absorb a large amount, but a lean clay and fine grained one may do the same. As a very general rule it may be stated that lean clays absorb from twelve to twenty per cent. of water, while fat clays anywhere from twenty to fifty per cent., and the more water a clay absorbs the more it has to part with in drying and the greater will be its shrinkage.

If green ware is dried too rapidly it may split, not only from differential shrinkage between the exterior and the interior surface, but the rapid escape of steam may, in the first stage of the burning, tend to burst the ware.

Highly aluminous clays do not always absorb the most water, nor are they the most plastic, and some clays low in alumina and high in organic matter are not only highly plastic but also absorb a large quantity of water.

In the manufacture of clay products the moisture is partly expelled by exposing the ware to the sun or putting it in heated tunnels or rooms, while the last traces of moisture are driven off in the early stages of burning.

Moisture may play another important and injurious role in clay working by its tendency to dissolve the soluble salts in the clay and bring them to the surface in drying, where they are left in the form of a white coating. It may also permit the acids which are contained in the fire gases of the kiln, to act on the mineral ingredients of the clay, and thus form soluble compounds, especially clorides and sulphates.

Combined water is present in every clay. In pure kaolin there is nearly 14 per cent. of it, in other clays the percentage depends on the amount of clay base and the presence of other hydrated minerals, such as limonite.

Combined water is driven off at a low red heat, and when this occurs the clay suffers an additional shrinkage. It is a curious fact that although the combined water does not determine the degree of plasticity of the clay, nevertheless when once driven off the clay can no longer be rendered plastic. The greater the amount of combined water, the greater the shrinkage, and in the burning the Alabama clays it varied from 2½ to 12 per cent.

PHYSICAL PROPERTIES OF CLAYS.

These are fully as important as chemical ones, if not more so, plasticity for instance being a character of enormous value.

The physical characters which are of the most importance from the practical standpoint, are plasticity, fusibility, shrinkage, tensile strength, slaking, absorption and density.

PLASTICITY.

This is the property by virtue of which a clay can be moulded into any desired form when wet, which shape is retained by it when dry.

Just what the cause of plasticity is still remains to be definitely proven, although several theories, some of them very reasonable ones, have been advanced. It is an exceedingly variable property and we can find all stages in the transition from the highly plastic clay to the slightly coherent sand. Clays, which posses little plasticity are said to be lean, while highly plastic ones are called fat.

Pure or nearly pure kaolins are nearly always lean, while clays low in kaolinite may be highly plastic, thus for instance the clay from Chalk Bluff, and the stoneware from Prattville, containing respectively 36.50 and 26.98 per cent. of alumina are both lean, while the clays from Fayette Court House and Fernbank containing only 19.68 and 13 per cent. of alumina respectively are both highly plastic.

Cook has shown that the plasticity of some kaolins may be increased by grinding them, the result being to tear apart the little particles of clay which were bunched or clustered together and thus permit a greater mobility of the grains or scales of clay over each other.

Mica decreases the plasticity of clay, and if, in a finely divided condition, tends to make it flaky when wet.

Plasticity, whatever its cause, is an important property from a commercial standpoint and highly interesting from a scientific one. The amount of water required to develop the maximum plasticity varies. If too little is added the clay cracks in moulding and is stiff and hard to work; if too much is mixed in with the clay it becomes very soft and retains its shape with difficulty. Lean clays usually require less water to produce a workable mass than plastic ones.

The Alabama clays require from 25 to 30 per cent. of water to develop their maximum plasticity.

TENSILE STRENGTH.

The tensile strength or the binding power of a clay often stands in relation to its plasticity, but not always. It exerts an important effect in connection with the cracking of the ware in drying. The common method of determining it is to form the plastic clay into briquettes of the same shape as those used in the testing of cement. When air-dried they are tested in the regular cement testing machine, and their tensile strength per square inch is determined. Before breaking, the cross section of the briquette must be carefully measured, as the clay shrinks in drying and the tensile strength per square inch has to be calculated from this sectional area.

The tensile strength of air-dried clays is extremely variable. In kaolins it is from 5 to 10 pounds per square inch; in brick clays 60 to 75 pounds per square inch and even 100 pounds; in pottery clays from 150 to 175 pounds.

Some very plastic clays show as much as 200 and 300 pounds per square inch, and a tensile strength of even 400 pounds has been recorded.

The strongest Alabama clay were the highly plastic one from Chalk Bluff, which had a maximum tensile strength of 384 pounds per square inch, while the Choctaw County one showed only 5 pounds per square inch.

The Alabama clays were all ground and passed through a thirty mesh sieve before testing.

Very fine grained clays seem to be lacking in tensile strength as they are in plasticity.

SHRINKAGE.

All clays undergo a shrinkage in drying and an additional shrinkage in burning, the first is known as air —, the second as fire-shrinkage. Some clays shrink most in drying, others most in burning, and consequently the amount is variable and depends on the amount of water absorbed, on the amount of lime in the clay, the quantity of organic matter, the size of the grain, and the amount of combined water.

The amount of water absorbed, and the texture influence the air-shrinkage which begins as soon as the water commences to evaporate from the clay. It has already been mentioned that a clay keeps on losing in weight after the shrinkage has ceased, and this fact is well shown by the following experiments on some Alabama samples.

The clay was from property of J. C. Bean, Sec. 31, T. 20, R. 11 w.

After moulding, the clay weighed	35.698	grams.
At end of 24 hours the shrinkage was 11½ per cent. and the weight	30.891	"
At end of 48 hours, shrinkage 12 per cent., weight	29.588	"
At end of 6 days, shrinkage 12 per cent., weight	29.460	"
At end of 8 days, shrinkage 12 per cent., weight	29.140	"
At end of 12 days, shrinkage 12 per cent., weight	29.093	"

Throughout this period the clay was kept exposed to a temperture of 70° Fahr.

The shrinkage is generally equal in all three directions, and consequently only the linear shrinkage is given. The greater the shrinkage of a clay the more danger there is of its cracking and warping in burning, and when there is any apprehension that this may occur, an attempt is made to prevent it by the addition of grog (burned clay) which diminishes the shrinkage.

Coarse grain clays having larger pores permit the water to escape more rapidly, and hence can be dried more quickly than fine grained ones, from which the water can not very readily escape. If the drying of fine grained clays is hastened, the surface shrinkage is more rapid than that of the interior and cracking ensues. We might perhaps expect that on account of their greater porosity, the fine grained clays would absorb more water, and consequently shrink more in drying. but the Alabama clays do not always bear out this fact.

The fire shrinkage generally commences when the combined water begins to pass off, and it may be just as variable as the air shrinkage. In fine grained clays, as those from near Prattville, the shrinkage from burning was found to be comparatively uniform, while on the other hand moderately fine grained kaolin from Rock Run shrank more rapidly as it approached the temperature of vitrification.

Sometimes the clay instead of shrinking during the burning appears to expand; and this is especially the case with very quartzose ones, for the quartz has the property of expanding at high temperatures. This expansion of siliceous clays may sometimes be responsible for the presence of cracks in the burned ware.

As the addition of quartz to diminish the shrinkage also tends to decrease the tensile strength of the clay, there will be a certain limit beyond which it must not proceed.

Organic matter and combined water tend to increase the shrinkage in burning, but lime has the oposite tendency.

Clays containing a large amount of feldspar will, in stead of showing a steady shrinkage up to the temperature of complete vitrification, often exhibit a temporary increase of volume when the fusing point of the feldspar is reached.

The shrinkage of most clays in burning does not proceed regularly and steadily up to the temperature of vitrification, for some clays attain their maximum density at a comparatively low temperature, below that at which they vitrify. Thus the plastic clay of J. C. Bean, near Tuscaloosa, attains its maximum shrinkage at cone 5, but does not vitrify until cone 27.

Between the point at which the moisture seems to pass off and that at which the combined water begins to escape, the clay shrinks little or none at all, and consequently the heat can be raised rapidly in this interval, but above and below these two points it must proceed slowly to prevent cracking or warping of the ware.

FUSIBILITY OF CLAYS.

It can be said in general, that other things being equal, the fusibility of a clay will increase with the all the fuxing impurities do not act with the same in-approximate statement however, for in the first place all the fluxing impurities do not act with the same intensity, and of two clays containing the same amount and kind of fluxes, that one which has the finer grain will usually fuse at the lower temperature, in addition to this the condition of the fire, whether oxidizing or reducing, also exerts an effect.

White mica tends to increase the refractoriness of a clay, and to exert very little fluxing action even at moderatly high temperatures.

As a clay is gradually heated, it not only shrinks, but also begins to harden. At the temperature at which the combined water begins to pass off, the impure clays acquire such a degree of hardness that they can no longer be scratched by a knife; but in the case of purer clays, the temperature must be raised much higher to obtain this same degree of hardness. This condition is brought about by the clay particles beginning to soften under the action of the heat, in other words it represents the very first stages of melting or incipient fusion, and in this condition the clay particles stick to each other, and bind the whole together into a solid mass. In clays which have been burned to incipient fusion, the particles are however still recognizable. If the temperature be increased, a variable amount, depending upon the clay, the result is that all of the particles become sufficently soft to permit their adjustment into a condition of greater compactness, leaving no interspaces, or in other words, the clay becomes impervious. This condition is spoken of as virtification, or complete sintering. The particles of the clay are no longer recognizable, and the maximum shrinkage has been reached. With a further elevation of the temperature the clay mass fusses completely, and becomes viscous or flows.

We therefore can recognize three stages in the burning of the clay, i. e., incipient fusion, vitrification and viscosity.*

The points of incipient fusion and viscosity may be within 75 degrees Fahr. of each other as in calcareous clays, while in some fire clays they may be as much as 500 or 600 degrees apart, and furthermore the point of vitrification does not necessarily lie midway between the two.

Most clays show a difference of from 200 to 400 degrees Fahr. between the points just mentioned, and it can be easily understood the farther apart these two points, the safer will it be to burn the clay, for it is not always possible to control a kiln within a range of a few degrees of temperature, and therefore in burning a mass of ware to vitrification if this point lies too near that of viscosity, there is danger of overstepping it and reaching the latter.

The fusibility of a clay depends on:

1. The amount of fluxes.
2. Size of the grain of the refractory and the non-refractory constituents.
3. The condition of the fire, whether oxidizing or reducing.

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*These three terms have been suggested by H. A. Wheeler, Vitrified Paving Brick, 1895.

Attempts have been made to express the relative fusibiliy of clays numercally, and this number has been called the *refractory quotient* by Bishop* and the fusibility factor by Wheeler.§ In both cases, the figure is obtained by using the non-fluxing elements of the clay for the numerator, and the fluxing impurities as a denominater; and in the case of the second formula, the fineness of the grain was also taken into consideration. As this mode of expressing the fusibility has not come into general use, the reference is simply given here.

On the other hand, it is customary to express the fusibility of the clay in degrees of temperature, and this temperature is measured by one or another form of pyrometer, whose principle depends on the fusion of alloys or single metals; thermo-electricity; fusion of an artificial mixture; spectro photometry; expansion of gases or solids; etc. Many of these are only applicable at lower temperatures, others are largely influenced by the personal equation, and only two or three of the most important will therefore be mentioned here.

THE THERMO-ELECTRIC PYROMETER.

Le Chatelier's Thermoelectric pyrometer depends on the measurement of a current generated by the heating of a thermo-pile. The latter consists of two wires, one of platium, the other an alloy, 90 per cent. platinum and 10 per cent of rhodium, twisted together at their free ends for a distance of about an inch, while the next foot or two of their lenth is enclosed in a fire clay tube so that when the couple is inserted into the

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*Die Feuerfesten Thone, p. 71, 1876.

§ English and Mining Journal, March 10, 1894.

furance only the end which is held near the body whose temperature is to be measured, will receive the full force of the heat. The two wires connect with a galvanometer, the deflection of whose needle increases with the temperature at the point of the free end of the wire couple. As at present put on the market, the thermo-electric pyrometer, costs about $180 and this, together with the delicacy of the galvanometer, has tended to restrict its use. There is no reason however why one should not be made and put on the market for a much lower price. It is not necessary that the recording instrument should be in immediate vicinity of the kiln, but it may be kept in another room where it is safe from dust and rough handling, and wires can extend from there to the kiln. This pyrometer is considered to be accurate to within 10 degrees Fahr.

SEGER PYRAMIDS.

These consists of different mixtures of kaolin and fluxes, which are compounded so that there shall be a constant difference between their fusing points. Segar's series were numbered from one to twenty, and the difference between any two consecutive numbers is 36 degrees Fahr. A later series introduced by Cramer runs from .01 to .022 with a difference of 54 degrees Fahr. between their fusing points, and in addition the higher numbers in the Segar series have been extended from number twenty up to number thirty-six. As these cones have been recently recalibrated, the fusing points of the various numbers together with their composition is given herewith.*

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* Taken from a recently issued circular of Thon industrie Saboratorium in Berlin, where the cones are and were originally made.

No. of Cone.	Composition.			Fusion Point Cent.	Fusion Point Fahr.
022	0.5 Na_2O 0.5 PbO	—	2 SiO_2 1 B_2O_3	590	1094
021	0.5 Na_2O 0.5 PbO	0.1 Al_2O_3	2.2 SiO_2 1 B_2O_3	620	1148
020	0.5 Na_2O 0.5 PbO	0.2 Al_2O_3	2.4 SiO_2 1 B_2O_3	650	1202
019	0.5 Na_2O 0.5 PbO	0.3 Al_2O_3	2.6 SiO_2 1 B_2O_3	680	1256
018	0.5 Na_2O 0.5 PbO	0.4 Al_2O_3	2.8 SiO_2 1 B_2O_3	710	1310
017	0.5 Na_2O 0.5 PbO	0.5 Al_2O_3	3 SiO_2 1 B_2O_3	740	1364
016	0.5 Na_2O 0.5 PbO	0.55 Al_2O_3	3.1 SiO_2 1 B_2O_3	770	1418
015	0.5 Na_2O 0.5 PbO	0.6 Al_2O_3	3.2 SiO_2 1 B_2O_3	800	1472
014	0.5 Na_2O 0.5 PbO	0.65 Al_2O_3	3.3 SiO_2 1 B_2O_3	830	1526
013	0.5 Na_2O 0.5 PbO	0.7 Al_2O_3	3.4 SiO_2 1 B_2O_3	860	1580
012	0.5 Na_2O 0.5 PbO	0.75 Al_2O_3	3.5 SiO_2 1 B_2O_3	890	1634
011	0.5 Na_2O 0.5 PbO	0.8 Al_2O_3	3.6 SiO_2 1 B_2O_3	920	1680
010	0.3 K_2O 0.7 CaO	0.2 Fe_2O_3 0.3 Al_2O_3	3.50 SiO_2 0.50 B_2O_3	950	1742
09	0.3 K_2O 0.7 CaO	0.2 Fe_2O_3 0.3 Al_2O_3	3.55 SiO_2 0.45 B_2O_3	970	1778

No. of Cone.	Composition.			Fusion Point Cent.	Fusion Point Fahr.
08	$0.3\ K_2O$ $0.7\ CaO$	$0.2\ Fe_2O_3$ $0.3\ Al_2O_3$	$3.60\ SiO_2$ $0.40\ B_2O_3$	990	1814
07	$0.3\ K_2O$ $0.7\ CaO$	$0.2\ Fe_2O_3$ $0.3\ Al_2O_3$	$3.65\ SiO_2$ $0.35\ B_2O_3$	1010	1850
06	$0.3\ K_2O$ $0.7\ CaO$	$0.2\ Fe_2O_3$ $0.3\ Al_2O_3$	$3.70\ SiO_2$ $0.30\ B_2O_3$	1030	1886
05	$0.3\ K_2O$ $0.7\ CaO$	$0.2\ Fe_2O_3$ $0.3\ Al_2O_3$	$3.75\ SiO_2$ $0.25\ B_2O_3$	1050	1922
04	$0.3\ K_2O$ $0.7\ CaO$	$0.2\ Fe_2O_3$ $0.3\ Al_2O_3$	$3.80\ SiO_2$ $0.20\ B_2O_3$	1070	1958
03	$0.3\ K_2O$ $0.7\ CaO$	$0.2\ Fe_2O_3$ $0.3\ Al_2O_3$	$3.85\ SiO_2$ $0.15\ B_2O_3$	1090	1994
02	$0.3\ K_2O$ $0.7\ CaO$	$0.2\ Fe_2O_3$ $0.3\ Al_2O_3$	$3.90\ SiO_2$ $0.10\ B_2O_3$	1110	2030
01	$0.3\ K_2O$ $0.7\ CaO$	$0.2\ Fe_2O_3$ $0.3\ Al_2O_3$	$3.95\ SiO_2$ $0.05\ B_2O_3$	1130	2066
1	$0.3\ K_2O$ $0.7\ CaO$	$0.2\ Fe_2O_3$ $0.3\ Al_2O_3$	$4\ SiO_2$	1150	2102
2	$0.3\ K_2O$ $0.7\ CaO$	$0.1\ Fe_2O_3$ $0.4\ Al_2O_3$	$4\ SiO_2$	1170	2138
3	$0.3\ K_2O$ $0.7\ CaO$	$0.05\ Fe_2O_3$ $0.45\ Al_2O_3$	$4\ SiO_2$	1190	2174
4	$0.3\ K_2O$ $0.7\ CaO$	$0.5\ Al_2O_3$	$4\ SiO_2$	1210	2210
5	$0.3\ K_2O$ $0.7\ CaO$	$0.5\ Al_2O_3$	$5\ SiO_2$	1230	2246
6	$0.3\ K_2O$ $0.7\ CaO$	$0.6\ Al_2O_3$	$6\ SiO_2$	1250	2282

No. of Cone.	Composition.			Fusion Point Cent.	Fusion Point Fahr.
7	0.3 $K_2 O$ 0.7 $Ca O$	0.7 $Al_2 O_3$	7 $Si O_2$	1270	2318
8	0.3 $K_2 O_3$ 0.7 $Ca O$	0.8 $Al_2 O_3$	8 $Si O_2$	1290	2354
9	0.3 $K_2 O$ 0.7 $Ca O$	0.9 $Al_2 O_3$	9 $Si O_2$	1310	2390
10	0.3 $K_2 O$ 0.7 $Ca O$	1.0 $Al_2 O_3$	10 $Si O_2$	1330	2426
11	0.3 $K_2 O$ 0.7 $Ca O$	1.2 $Al_2 O_3$	12 $Si O_2$	1350	2462
12	0.3 $K_2 O$ 0.7 $Ca O$	1.4 $Al_2 O_3$	14 $Si O_2$	1370	2498
13	0.3 $K_2 O$ 0.7 $Ca O$	1.6 $Al_2 O_3$	16 $Si O_2$	1390	2534
14	0.3 $K_2 O$ 0.7 $Ca O$	1.8 $Al_2 O_3$	18 $Si O_2$	1410	2570
15	0.3 $K_2 O$ 0.7 $Ca O$	2.1 $Al_2 O_3$	21 $Si O_2$,	1430	2606
16	0.3 $K_2 O$ 0.7 $Ca O$	2.4 $Al_2 O_3$	24 $Si O_2$	1450	2642
17	0.3 $K_2 O$ 0.7 $Ca O$	2.7 $Al_2 O_3$	27 $Si O_2$	1470	2678
18	0.3 $K_2 O$ 0.7 $Ca O$	3.1 $Al_2 O_3$	31 $Si O_2$	1490	2714
19	0.3 $K_2 O$ 0.7 $Ca O$	3.5 $Al_2 O_3$	35 $Si O_2$	1510	2750
20	0.3 $K_2 O$ 0.7 $Ca O$	3.9 $Al_2 O_3$	39 $Si O_2$	1530	2786

[illegible]	Composition.		[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	1550	2822
[illegible]	[illegible]	[illegible]	1570	2858
[illegible]	[illegible]	[illegible]	1590	2894
[illegible]	[illegible]	[illegible]	1610	2930
[illegible]	[illegible]	[illegible]	1630	2966
[illegible]	[illegible]	[illegible]	1650	3002
[illegible]	[illegible]	[illegible]	1670	3038
[illegible]	[illegible]	[illegible]	1690	3074
[illegible]	[illegible]	[illegible]	1710	3110
[illegible]	[illegible]	[illegible]	1730	3146
[illegible]	[illegible]	[illegible]	1750	3182
[illegible]	[illegible]	[illegible]	1770	3218
[illegible]	[illegible]	[illegible]	1790	3254
[illegible]	[illegible]	[illegible]	1810	3290
[illegible]	[illegible]	[illegible]	1830	3326
[illegible]	[illegible]	[illegible]	1850	3362

The theory of these pyramids is that the cone bends over as the temperature approaches its fusing point, and when this is reached, the tip touches the base. If the heat is raised too rapidly, those cones which contain much iron swell and blister and do not bend over, and the best results are obtained by the slow softening of the cone under a gradually rising temperature.

For practical purposes these cones are considered sufficiently accurate.

In actual use they are placed in the kiln at a point where they can be watched through a peep-hole but at the same time will not receive the direct touch of the flame from the fuel. It is always well to put two or more cones in the kiln so that warning can be had not only of the approach of the desired temperature but also of the rapidity with which the temperature is rising.

In order to determine the temperature of a kiln several cones of separated numbers are put in,as for ex. .07, 1, and 5. Suppose .07 and 1 are bent over in burnng but 5 is not affected, then the temperature of the kiln was between one and five; the next time 2, 3, and 4 are put in, and 2 and 3 may be fused but 4 remain unaffected, indicating that the temperature reached the fusing point of three.

These pyramids have been much used by foregin manufacturers of clay products and are coming into use in the United States. Numbers .01 to 10 can be obtained for one cent each from Prof. E. Orton, Jr., Ohio State University, Columbus, Ohio.

It is rather difficult to compare the thermo-electric pyrometer with Seger pyramids and say that either one or the other is better. The latter are well adapted to judge the completion of the burning. That is it may take the same amount of heat to burn a certain ware to the proper condition, as it does to bend over cone 5,so that when the latter goes over the burning is done.

The cones do not however show whether the temperature of the kiln is rising steadily or fast at one time and slow at another, or again whether or not it may have dropped temporarily.

All of these last mentioned conditions are shown by the thermo-electric pyrometer, and a comparison of conditions during burning, with the results obtained, may lead to a discovery of those conditions that will produce the best product.

CHEMICAL EFFECTS OF HEATING.

While the fusion of a clay may be looked upon in part as a chemical action, there are other changes which take place in the clay before the temperature of fusion is reached. These changes are:

The driving off of the chemically combined water.

The burning of the organic matter.

The change of limonite to hematite by the loss of its combined water.

The oxidization of pyrite to sulphate which by further heating loses its sulphur and is also converted into hematite.

The driving off of carbonic acid from any carbonates of lime or magnesia which may be present.

The general effect of these changes is first to make the clay more porous, but subsequently to increase its shrinkage, and in addition the color of the clay is changed.

A chemical interaction between the components of the clay only begins with incipient fusion.

SLAKING.

Clays, when thrown into water, break up more or less completely, or in other words, they slake. The process is simply one of mechanical disintegration, which, however, has important practical bearings. Some homogeneous clays on being immersed split into a number of angular fragments, while others flake off into scaly particles, while still others crumble down to a powder. This slaking action proceeds slowly or quickly depending on the toughness or density of the clay. Some clays slake completely in two or three minutes, while others may be little effected by an immersion in water of an hour or two.

The practical importance of slaking is noticed first in the case of clays which have to be washed for marketing, for the quicker they fall apart when they are thrown into water, the more rapid and sometimes the more thoroughly will be the elimination of the impurities.

In the tempering the easy slaking of a clay is also of importance, permitting it to be more easily broken up and the more thoroughly mixed with water.

ABSORPTION.

This varies with the amount of organic matter, ferric hydrate, and the porosity of a clay, and increases with all three. As has already been stated the more water a clay absorbs the more it has to give off in drying and the more difficult it is, especially in the case of fine grained clays, to avoid cracking.

COLOR OF UNBURNED CLAYS.

Ferric oxide and organic matter are the two great coloring agents of the raw clay. Organic matter generally colors a clay gray, bluish gray, or black, while iron according to the condition of the oxide, or the presence of carbonate, may impart a red, yellow brown, or sometimes a gray color.

For any given amount of organic matter or ferric oxide, the coloration will be much more intense the more sandy the clay.

In general it may be said that, organic matter excepted, the purer clays are usually light colored, while the impure ones are yellow, red, or brown.

Organic matter however, frequently masks the iron coloration, and makes it often difficult to determine the refractory nature of the material. Some clays which burn perfectly white may be colored black by organic matter as in the case of the sand clay from Pegram. Ferrous compounds not infrequently impart a gray or bluish tint to clay, and at times the lower part of a clay bed may be gray while the upper portion is yellow or red, due to the oxidation of the iron contained in it.

THE MINERALOGY OF CLAYS.

Most clays are so fine grained that it is impossible to determine the mineral constituents with the naked eye, and their recognition even microscopically, is sometimes a matter of diffculty. At the same time however, there are certain minerals, which are either present in all clays or are to be found in a great many of them, and these will be mentioned in the order of their abundance.

KAOLINITE.

The mineral kaolinite is looked upon as the base of all clays, and while it is not wanting so far as we know in any of them, nevertheless, it is not as abundant as we have been apt to consider it, nor are the characteristic properties of clay wholly due to it.

Kaolinite, whose formula is Al_2O_3, $2SiO_2$, $2H_2O$, or silica 46.3 per cent., alumina 39.8 per cent., water 13.9 per cent is a white scaly mineral crystallizing in the monoclinic system, the crystals presenting the form of small hexagonal plates. Its specific gravity is 2.2

to 2.6 and its hardness is 2 to $2\frac{1}{2}$. It is naturally white in color and plastic when wet but very slightly so. The microscope shows the kaolinite to be collected in little bunches which can be broken apart by grinding and thereby increasing the plasticity.*

Kaolinite is nearly infusible but a slight addition of fusible impurities lowers its refractoriness. A mass of kaolinite is called kaolin, and pure kaolin is practically unknown.

Many kaolins contain very minute scales of white mica, which under the microscope are hardly distinguishable from kaolinite. It is not to be inferred that kaolinite always occurs in hexagonal plates, for in some clays scales of six sided outline are almost wanting.

QUARTZ.

This mineral is present in sedimentary clays mostly in the form of rounded grains, and sometimes in crystals, while in residual clays the particles are most commonly angular. It is an extremely hard mineral, which will scratch glass and possesses a shell like or conchoidal fracture, it is practically not attacked by the common acids, but is affected by alkaline solutions. This is one of the few mineral components of clay which, at times, occurs in grains of sufficient size to be recognized by the unaided eye. It may be colorless but the surface of the grain is not infrequently stained by a thin film of iron oxide. Feldspar might be mistaken for it, but the latter will not scratch glass.

Flint or non-crystalline silica is sometimes present in clays. It usually has a muddy color and a conchoidal fracture.

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*G. H. Cook, Clays of New Jersey, Geological Survey, 1878.

Both quartz and flint are infusible at very high temperatures but the presence of other minerals may serve to flux them. Quartz tends to diminish the shrinkage of the clay, and if wanting it has to be added during the process of manufacture. Its addition also tends to decrease the plasticity.

CALCITE.

This mineral which is carbonate of lime, effervesces when moistened with muriatic acid, so that its presence in clay may often be detected by the addition of this chemical. Calcite is a soft mineral and occurs in the clay, either in the form of little rhombohedral or powdery particles. Clays, which contain a large amount of it in finely divided condition, are said to be marly, and in some clay deposits certain layers may contain a larger percentage of carbonate of lime than others. The carbonate of lime found in clays may be derived from particles of limestone in the clay if it is a sedimentary one, or from the decomposition of lime-soda feldspar in the case of either sedimentary or residual deposits. Percolating water may also introduce it into the clay.

GYPSUM.

Gypsum or the sulphate of lime is found in clay in the form of grains, needles, well developed crystals, or lamellar masses. It is so much softer than calcite that it can be scratched by the finger nail, often has a pearly lustre, is transparent, and does not effervesce when acid is poured on it. In hard burned brick gypsum simply acts as a flux, but in lightly burned ones it gives rise to soluble sulphates which cause efflorescence.

MICA.

This mineral can be frequently detected by the naked eye, owing to its high lustre, even when it is present in the form of very minute scales. It is seldom absent in clays and is usually found to an appreciable extent in even the best kaolins, for on account of its scaly nature and lightness, it remains suspended in water for a long while and is consequently very hard to remove by washing; small amounts of white mica are rarely injurious.

Mica is usually found in those clays which have been derived from the breaking down of igneous or metamorphic rocks, such as granites, gneisses or schists, and two species are recognized in clay, i. e. biotite and muscovite. The former is a complex silicate of iron, magnesia, and alumina, and occurs as six sided plates or irregular scales usually of a dark color. As it easily decomposes with the formation of iron oxide, it is not so apt to be found in clays as the muscovite, which is more resistant to weathering. The muscovite is sometimes called potash mica, although it also contains a small amount of iron and magnesia; it is of silvery white or light brown color.

Mica decreases the plasticty of clay, and tends to make it flaky when wet, if in a finely divided condition.

White mica tends to increase the refractoriness of a clay, and to exert very little fluxing action, even at moderately high temperatures.

IRON OXIDE.

This, next to quartz, is perhaps the commonest mineral impurity of clay. It occurs as earthy grains, as metallic scales or as a superficial coating on other mineral grains found in the clay. It dissolves quietly in muriatic acid. Iron may also occur in the clay as a constituent element of many silicates, and indeed the effect which it produces may be caused not so much by the actual amount of iron oxide which is present, but by the condition which it is in.

Iron oxide is very apt to form concretions in the clay, and these concretions which generally have a shell-like structure, vary in diameter commonly from a fraction of an inch to several inches. Siderite, the carbonate of iron, which is also to be found in many clays, likewise forms concretions or opaque rounded masses, which effervesce on the addition of warm muriatic acid. The exterior of these siderite concretions is not unfrequently altered to limonite, the brown or yellowish hydrated oxide of iron. Such concretions are hard and rock-like in their nature, and either have to be separated by screening the clay before using, or crushed by passing the clay between rolls.

PYRITE.

This mineral is a compound of iron and sulphur, and the grains of it are easily recognized by their metallic lustre and their yellow color. It is a very common constituent of many fire clays, and occurs either in the form of small grains or concretionary masses of yellow crystals. Its bright metallic surface will serve to distinguish it from limonite which has a dirty appearance.

DOLOMITE.

This is a double carbonate of lime and magnesia, and may occur in a clay in the same form as calcite, and the effect of it is practically the same.

METHODS EMPLOYED IN MAKING CLAY ANALYSES.*

The following brief statement of the methods employed in making the analyses of clays for this report has been prepared by Dr. Charles Baskervill, by whom the analyses were made:

Moisture—Two grams are heated in a platinum crucible at 100° C. until they show a constant weight. The loss is reported as moisture.

Loss on Ignition (combined water, and sometimes organic matter, etc.)—The crucible and clay are heated with a blast lamp until there is no further loss in weight.

Alkalies—This same portion of clay, which has been used for determining moisture and loss, is treated with concentrated sulphuric and hydrofluoric acids until it is completely decomposed. The acids are evaporated off by heating upon the sand-bath. The cooled crucible is washed out with boiling water to which several drops of hydrochloric acid have been added. The solution after being made up to about five hundred cubic centimetres is boiled, one-half gram ammonia oxalate added and made alkaline with ammonium hydroxide; the boiling is continued until but a faint odor of ammonia remains. The precipitate is allowed to settle and is separated from the liquid by filtering and washed three times with boiling water. The filtrate is evaporated to dryness and ignited to drive off ammonia salts. The residue is treated with five cubic centimetres of boiling water, two or three cubic centimetres of saturated ammonium carbonate solution are added and the whole is filtered

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into a weighed crucible or dish. The precipitate is washed three or four times with boiling water and the filtrate evaporated to dryness. Five drops of sulphuric acid are added to the residue, and then the crucible or dish is brought to a hot heat, cooled in a desicator, and the alkalies are weighed as a sulphate.

To separate the alkalies, the sulphates are dissolved in hot water, acidified with hydrochloric acid, sufficient platinum chloride added to convert both sodium and potassum salts into double chlorides; the liquid is evaporated to a syrup upon a water-bath, eight per cent. alchohol added, and filtered through a Gooch crucible or upon a tared filter paper. The precipitate is thoroughly washed with eighty per cent. alcohol, dried at 100° C. and weighed; the potassium oxide is calculated from the double chloride of potassium and platinum.

When magnesium was present to as much as one-half of one per cent., the magnesium hydroxide was precipitated with barium hydroxide solution and the barium in turn removed by ammonium carbonate. When the amount of magnesium was less than the amount named, this portion of the ordinary process was not regarded as necessary.

Silica—Two grams of clay are mixed with ten grams of sodium carbonate and one-half gram of potassium nitrate and brought to a calm fusion in a platinum crucible over the blast lamp. The melt removed from the crucible is treated with an excess of hydrochloric acid and evaporated in a casserole to dryness upon a water-bath, and heated in an air-bath at 110° C. until all the hydrochloric acid is driven off. Dilute hydrochloric acid is added to the casserole now, and the solution brought to boiling and rapidly filtered.

The silica is washed thoroughly with boiling water and then ignited in a platinum crucible, weighed, and moistened with concentrated sulphuric acid. Hydroflouoric acid is cautiously added until all the silica has disappeared. The solution is evaporated to dryness upon a sand-bath, ignited and weighed. The difference in weight is silica.

Iron Sesquioxide—The filtrate from the silica is divided into equal portions. To one portion in a reducing flask is added metallic zinc and sulphuric acid. After reduction and filtration to free the liquid from undissolved zinc and carbon, the iron is determined by titration with a standard solution of potassium permanganate.

Aluminium Oxide--To the second portion, which must be brought to boiling, ammonium hydroxide is added in slight excess, the boiling continued from two to five minuts, the precipitate allowed to settle and then caught upon the filter, all of the chlorides being washed out with boiling water. The precipitate is ignited and weighted as a mixture of aluminium oxide and iron sesquioxide. The amount of iron sesquioxide already found is taken from this and the remainder reported as alumina.

Calcium Oxide—The filtrate from the precipitate of iron and aluminium hydroxides is concentrated to about two hundred cubic centimetres, and the calcium precipitated in a hot solution by adding one gram of ammonium oxalate. The precipitate is allowed to settle during twelve hours, filtered and washed with hot water, ignited and weighed as calcium oxide. When the calcium is present in notable amounts, the oxide is converted into the sulphate and weighed as such.

Magnesium Oxide—The filtrate from the calcium oxalate precipitate is concentrated to about one hundred cubic centimetres, cooled, and the magnesium precipitated by means of hydrogen disodium phosphate in a strongly alkaline solution, made so by adding ten cubic centimetres of ammonium hydroxide (0.90 sp. gr.). The magnesium ammonium phosphate, after standing over night, is caught upon an ashless filter, washed with water containing at least five per cent. ammonium hydroxide, burned and weighed as magnesium pyrophosphate.

The *insoluble residue* is determined by digesting two grams of clay with twenty cubic centiments of dilute sulphuric acid for six or eight hours on a sand-bath, the excess of acid being finally driven off. One cubic centimetre of concentrated hydrochloride acid is now added and boiling water. The insoluble portion is filtered off, and after being thoroughly washed with boiling water is digested in fifteen cubic centimetres of boiling sodium hydroxide of ten per cent. strenth. Twenty-five cubic centimetres of hot water are added and the solution filtered through the same filter paper, the residue being washed five or six times with boiling water. The residue is now treated with hydrochloric acid in the same manner and washed upon the filter paper, and free from hydrochloric acid, is burned and weighed as insoluble residue.

A portion of this is treated as the original clay for silica, aluminium oxide and iron oxide. Another portion is used for the determination of the alkalies in the insoluble residue.

Titanic Oxide—One-half gram of clay is fused with five grams potassium bisulphate and one gram sodium fluoride in a spacious platinum crucible. The melt is dissolved in five per cent. sulphuric acid. Hydrogen dioxide is added to an aliquot part and the tint compared with that obtained from a standard of titanium sulphate.

Sulphur (total present)—The sulphur is determined by fusing one-half gram of clay with a mixture of sodium carbonate, five parts, and potassium nitrate, one part. The melt is brought into solution with hydrochloric acid. The silica is separated by evaporation, heating, resolution, and subsequent filtration. Hydrochloric acid is added to the filtrate to at least five per cent. and the sulphuric acid is precipitated by adding barium chloride in sufficient excess, all solutions being boiling hot. The barium sulphate is filtered off and washed with hot water, burned and weighed as such.

Ferrous Oxide—is determined by fusing one-half gram of clay with five grams sodium carbonate, the clay being well covered with the carbonate, the top being upon the crucible. The melt is dissolved in a mixture of dilute hydrochloric and sulphuric acids in an atmosphere of carbon dioxide. The ferrous iron is determined at once by titration with a standard potassium permanganate solution.

The *rational analysis* is made from the results obtained by the chemical analysis in the following way: The alumina found in the portion insoluble in sulphuric acid and sodium hydroxide is multiplied by 3.51. This factor has been found to represent the average ratio between alumina and silica in orthoclase feldspar; therefore the product just obtained would represent the amount of silica that would be present in undecomposed feldspar. The sum of this silica with the alumina, ferric oxide and alkalies equals the "feldspathic detritus." The difference between silica as calculated for feldspar and the total silica in the insoluble portion represents the "quartz" or "free sand." The difference between that portion of the sample insoluble in sulphuric acid and sodium hydroxide and the total represents the "clay substance." The method of analysis used to detrmine the mineralogical character of the clay is called the *rational* method, and when carried out in its simplest form, determines the amount of clay substance or kaolinite, quartz, and feldspar present 'n the clay. If carried out more completely, it enables us to calculate the amount of calcite or limestone (calcium carbonate)' iron oxide and even mica in the clay.

THE RATIONAL ANALYSIS OF CLAY.

The rational analysis of clay consists in resolving the clay into its mineralogical elements, thus giving a clue to its physical as well as its chemical properties. It is often utilized by manufacturers of porcelain and other high grades of ware as a guide in the compounding of their mixtures.

The ordinary quantitative or ultimate analysis regards the clay as a mixture of oxide of the elements, although they may be present in entirely different combinations, such as silicates, carbonates, hydrates, sulphates, etc. This condition of combination is important for it makes a difference in the behavior of the clay. Thus for instance, if silica is present in the form of quartz it will decrease the shrinkage and also increase the refractoriness up to a certain point, but if present as a component element of feldspar it serves as a flux and also increases the plasticity somewhat.

It is not intended though that the rational analysis shall fully supplant the ultimate one for each serves its own purpose.

The ultimate analysis may be used to supply information on the following points.

1. The purity of the clay, by showing the proportions of silica, alumina, combined water and fluxing impurities.

2. From the ultimate analysis we can form a general idea regarding the refractoriness of the clay, for, other things being equal the greater the total sum of the fluxing impurities, the more fusible the clay.

3. The color to which the clay burns may also be judged approximately for the greater the amount of iron in the clay the deeper red will it burn, provided the iron oxide is evenly distributed, and there is not an excess of lime in the clay. If the proportion of iron to lime is as 1; 3, then a buff product results, provided the clay is only heated to incipient fusion or vitrification. The above conditions will be affected by a reducing atmosphere in burning or of sulphur in the fire gases.

4. Clays with a large amount of combined water sometimes exhibit a tendency to crack in burning. This combined water would be shown in the ultimate analysis.

5. A large excess of silica would indicate a sandy clay.

The connection between refractoriness and chemical composition may be illustrated by the following analysis.

The following analyses indicate this fact:

	1	2	3
	Per cent.	Per cent.	Per cent
SiO_2	47.20	69.50	54.90
Al_2O_3	36.50	13.00	18.03
Fe_2O_3	2.56	6.40	6.03
CaO	tr.	.25	2.88
MgO	tr.	tr.	1.10
Alkalies		tr.	3.40
H_2O	13.35	6.70	6.90
Moisture	.50	3.40	3.17
Total fluxes	2.56	6.65	13.41
	DEG. F.	DEG. F.	DEG. F.
Viscosity or fusion point.	Above 2700	2300	1900

1. Chalk Bluff, Marion Co., Ala., *U. S. Geol. Surv.* 18th *Ann. Rep.*, Part V. (continued), p. 1128.
2. Fernbank, Lamar Co., Ala. *Ibid.*
3. Norborne, Mo. *Mo. Geol. Surv.*, XI. *Ann. Rep.*

This is practically the full extent to which the ultimate analysis can be used; and there still remain to be explained a number of physical facts concerning any clay which happens to be under consideration.

It frequently happens that two clays approach each other quite closely in their ultimate composition, and still exhibit an entirely different behavior when burned. The explanation which most quickly suggests itself is, that the elements present in the two clays are differently combined. Some method of resolving the clay into its mineral components, so as to indicate the condition in which the elements are present is therefore practically needed.

As kaolinite results from the decomposition of feldspar, the kaolin is quite sure to contain some undecomposed feldspar, and also some quartz, and (in smaller amounts) mica, since the two latter minerals are common associates of the feldspar.

If, now, we know the amount of feldspar, quartz and kaolinite or clay-substance in the kaolin, and the effect of these individual minerals, we can form a far better opinion of the probable behavior of the clay in burning.

When mica is present, it is dissolved out with the kaolinite and reckoned in as clay-substance, but it is rarely present in large amounts, and may perhaps alter the character of the clay-substance but little, for finely ground white mica possesses plasticity, and can be formed and dried without cracking. It is more refractory than feldspar, and holds its form up to 1400° C.*

In the following table are given the ultimate and rational analyses of a number of kaolins, which show how a constancy of ultimate composition may be accompanied by variations in the rational analysis:

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* G. Vogi, *Chem. News*, 1890, p. 315.

TABLE I.—*Ultimate and Rational Analyses of Clays.*

	1	2	3	4	5	6	7	8	9	10	11	12
	ULTIMATE ANALYSIS.											
SiO_2	62.40	62.52	63.17	64.87	63.07	54.51	53.10	47.60	46.61	58.39	46.82	57.08
Al_2O_3	26.51	25.57	25.09	23.83	24.67	31.41	33.06	34.00	36·47	27.52	38.49	29.94
Fe_2O_3	1.14	.92	.64	.83	.59	.68	1.18	1.30	2.81	.36	1.09	.65
CaO	.57	.65	.35	....	....	.04	.38	Tr.	·14	1.52	....	....
MgO	·01	.10	.26	.50	.40	.43	.08	.50	....	.41	Tr.	.49
Alkalies	.98	1.04	.80	1.39	4.25	.55	.83	3.00	1.44	4.29	1.40	2.26
Loss by ignition	8.80	9.27	9.70	8.36	7.00	12.37	11.32	13.60	12.80	7.19	12.86	9.87
	100.41	100.07	100.01	99.78	99.98	99.99	99.95	100.00	100.27	99.68	100.66	100.29
	RATIONAL ANALYSIS.											
Clay-substance	66.33	72.05	67.82	63.77	54.92	83.04	83.39	88.34	96.08	55.88	96.55	74.09
Quartz	15.61	27.78	30.93	35.50	23.52	16.28	14.99	8.95	1.93	5.95	2.30	17.21
Felspar	18.91	.10	1.25	.73	21.56	.28	1.57	2.73	1.99	38.17	1.15	8.70
	100.85	99.93	100.00	100.00	100.00	100.0	99.95	100.02	100.00	100.00	100.00	100.00

1. Crude kaolin, Springer mine, Webster, N. C. *Bull, N. C. Geol. Surv.*, on "Clays of North Carolina."
2. Slip-clay from Ruhle's mine, Lothian, Saxony. *Thon.-Ind.-Zeit.*, 1892, p. 1031.
3, Slip-clay from Kaschkau, Germany, *Ibid.*
4, Kaolin from Sennewitz, Saxony. *Notizblatt*, 1876,
5, Porcelain-clay mixture, *Ibid.*
6, White earthenware clay, Lothain, Saxony, *Seger's Ges. Schr.*,p.887.
7. Kaolin (unwashed), West Mills, N. C. *Bull, N. C. Geol. Surv.*, on "Clays of North Carolina."
8. White earthenware clay, Wiesau, Germany. *Thon.-Ind.-Zeit.*, 1894, p. 358.
9. Fire-clay, Bautzen, Germany. *Ibid.*, 1894, p. 842.
10. Kaolin, Limoges, France. *Seger's Ges. Schr.*, p. 552.
11. Kaolin, Zettlitz, Bohemia. *Ibid.*, p. 50.
12. Kaolin, Lettin, Saxony. *Ibid.*, p. 50.

From this table a number of interesting conclusions may be drawn. Columns 1 and 2 represent two clays which agree very closely in their ultimate composition; but in the rational analysis there is a difference of 6 per cent. in the clay-substance, 12 per cent. in quartz, and nearly 19 per cent. in the feldspar. Nos. 3 and 5 and 10 and 12 also illustrate this point.

In Nos. 6 and 7, one a German, and the other a North Carolina kaolin, the ultimate analyses are very closely alike, and the rational analyses also agree very well. This is frequently the case when the clay-substance is very high, between 96 and 100 per cent., as in Nos. 9 and 11.

A third case would be presented if the rational analyses agreed, but the ultimates did not. Such instances, however, seem to be much less common.

The practical value of the rational analysis bears chiefly upon those branches of the clay-working industry, such as manufacture of porcelain, white earthenware, fire-brick and glasspots, which use materials with comparatively few fusible impurities (iron, lime, magnesia).

There is much concerning clays which sitll remains unexplained, but it seems probable that, other things being equal, two clays having the same *rational* composition will behave alike.

We can illustrate this point by the follownig tests made on washed kaolins from the vicinity of Sennewitz, near Halle, Germany. From the figures given below, it will be noticed that in the case of Nos. 1 and 2 there is a close agreement in the shrinkage, which amounted to about 10 per cent. when the clay was heated up to the temperature of a hard-porceclain kiln. In Nos. 3 and 4 the shrinkage is very nearly the same, but greater than in Nos. 1 and 2, because the rational composition has changed, there being a marked increase in the amount of feldspar.

If there hed been much difference in the size of the clay-particles of Nos. 3 and 4 or Nos. 1 and 2, the shrinkage in each case would probably have been different.

TABLE II.—*Rational Analysis and Shrinkage of Clays.*

Feldspar. Per cent.	Quartz. Per cent.	Clay-Substance. Per cent.	Fe_2O_3 Per cent.	Shrinkage in Hard Porcelain Fire Per cent
1.59	33.86	64.55	0.75	10.20
1.21	33.39	65.40	0.73	10.10
8.64	31.69	59.68	0.30	12.90
8.25	35.15	56.60	0.30	12.00

The degree of fineness of the clay-particles, and perhaps their shape also, probably exert more influence on the shrinkage than has been imagined, but just how far this makes itself felt is still undetermined.

As an illustration of the practical use of the rational analysis we may take the following:

Suppose that we are using for the manufacture of porcelain or fire-brick a kaolin which has 67.82 per cent. of clay-substance, 30.93 of quartz, and 1.25 of feldspar, and that to 100 parts of this is added 50 parts of feldspar. This would give us a mixture of 45.21 per cent. of clay substance, 20.62 of quartz, and 34.17 of feldspar.

If now for the clay we had been using, we substituted one with 66.33 per cent. of clay-substance, 15.61 of quartz, and 18.91 of feldspar, and made no other changes, the mixture would then contain 44.22 per cent. of clay-substance, 10.41 of quartz and 45.98 of feldspar.

This last mixture shows such an increase in feldspar that it must give much greater shrinkage and fusibility; but knowing the rational analysis of the new clay, it would be easy to add quartz or feldspar so as to bring the mixture back to its normal composition.

The application of the method of rational analysis to impure clays is not quite as satisfactory, but at the same time not as necessary. In the treatment, the iron, if present as oxide, and lime or magnesia, if carbanotes, are dissolved out with the clay-substance. The silicate minerals are grouped with the feldspar, and the clay thus becomes divided into clay-substance (kaolinite, ferric oxide, lime and magnesia carbonates), feldspar or feldspathic detritus; and quartz. If the percentage of ferric oxide and carbonates is high, it is necessary to determine them separately in the ultimate analysis.

In making a rational analysis, the clay is treated with strong sulphuric acid, which decomposes the kaolin into sulphate of alumina and hydrous silica. The former is soluble in water, while the latter is removed with caustic soda, and we get an insoluble residue consisting of quartz and feldspar. In this residue the alumina is determined and the feldspar calculated.

Another way of conducting the rational analysis, and one which is chiefly applicable when the clay contains other minerals besides the kaolin, quartz and feldspar, such as carbonate of lime, ferric oxide, or mica, consists in analysing the insoluble residue and calculating the mineral percentages from this.

THE CLASSIFICATION OF CLAYS.

As it is possible to find every gradation from the purest to the most impure clays any classification that is attempted, will necessarily be more or less unsatisfactory. It is of course possible primarily to make two great divisons i. e. residual and sedimentary, and to these might perhaps be added a third class of clays, namely, those formed by chemical precipitation. Under each of the first two classes, it would be possible again to find every gradation from pure to impure.

It is not possible to make any classification based upon the practical applications of the materials, for some clays are used for as many as four to five different purposes, and it is probable that some classification which simply recognizes four or five important groups is probably the most satisfactory and the least confusing. Hill makes the following divisions:*

China clays.
Plastic, ball, pottery clays.
Brick clays.
Refractory or fire clays.

He furthermore makes another table based on the origin of the clay as found in the United States:

I—WHITE BURNING CLAYS.

1. Rock or residual kaolin.
2. Indianite or Indiana kaolin.
3. Florida or sedimentary kaolins.
4. White burning plastic clays.

II—COLOR BURNING CLAYS.

Mixed clays—

1. Brick clays, (Siliceous).
2. Marly clays, (Calcareous).
3. Pink clays, (Ferruginous).
2. Cement clays, (Silico-calcareous).
5. Alum clays.

Altered clays (shale and slate).

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*U. S. Geol. Survey, Mineral Resources, 1893.

A classification which has been made by Seger, the great German Ceramic Chemist, gives:

1. *Yellow burning*, containing lime and iron.
2. *Red burning*, non-aluminous, ferruginous clays, which are free from lime.
3. *White and yellow burning*. These clays are low both in lime and iron.
4. *White burning*, low in iron and high in alumina.

THE MINING AND PREPARATION OF CLAYS.

RPOSPECTING FOR CLAYS.

Clay deposits are best seen in those regions where rivers and brooks have cut gullies and ravines, the clay showing on the sides of the cut. In such locations the thickness of the deposit and variation in its character vertically are well shown. Similar sections are to be loooked for along railroads. As the beds are apt to wash down it is necessary to clean the surface of the cut before taking any sample for testing, and even then great care must be observed to insure the sample being an average one.

Apart from cuts the presence of clay can often be determined by the character of the vegetation, the nature of the soil, or upturned tree roots.

The outcropping of clay in a ravine should not be depended on alone, but in addition borings should be made to determined the depth and extetnt of the deposit, and persistance of the different layers if there is a variation in them.

Shale often forms cliffs or steep slopes, at the base of which there may be a talus of partly weathered fragments and soft clay; in fact the outcrop of a shale deposit may be covered by the clay into which it has slaked under the influence of weathering. In some localities this mellowed outcrop may be only a few feet thick, but in many it is of sufficient volume to supply a small brick yard, without the necessity of attacking the fresh shale beneath.

MINING OF CLAYS*.

Clays, when soft and plastic, are mostly dug with pick and shovel, loaded on wheel-barrows, carts or cars and hauled to the works. If the deposit is broad and shallow the clay is usually dug at any convenient point; often any overlying sand or other useless material has been first removed and used for filling in or some other purpose.

If the bank is located on the hillside, and has considerable height, it is worked out in broad steps, the object of this being to prevent the bank from sliding in wet weather.

When the bank is near the works, wheel-barrows or carts can be used to haul the clay, but far distances, over 600 feet, it pays to lay tracks and use cars, hauled either by horse or steam power.

Underground methods of mining are only used in case the amount of overlying material is very great. It is chiefly used for shale deposits.

Steam shovels are employed for sandy clays or soft shales at some localities in the Uuited States, but most shales are mined by blasting, and the fragments thus loosened are sent to the works.

Where the clay is rough, and the face of the bank 12 or 15 feet high, a plan often followed is to undermine it by picking at the base, and then inserting large wooden wedges at the top. This brings down

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*This does not include the mining of kaolin, which is treated separately.

a large mass at once, the fall serving to break it up. While effective, this method is often attended with danger.

MINING OF KAOLIN.

Kaolin is usually sufficiently soft in nature to be mined by means of the pick and shovel. In some portions of the beds near Valley Head streaks of *halloysite* are found in the clay, which are quite hard, but they are of such a limited extent as not to cause much extra trouble. If the deposit is deep, narrow, or interbedded with other formations which are too thick to be removed by stripping, or if again the kaolin does not run regular in its composition, it is often advisable to follow the better portions of the bed, or the narrow vein if it is such, by means of shaft, levels, or slopes. These sometimes have to be timbered, at other times, as at Valley Head, they do not.

In the case of deposits which are large and broad, it is most economical to operate them as quarry workings or open pits, digging out the material and loading it on the cars or wheel-barrows which convey it to the washing plant. If a pit is large and broad the sides, instead of being dug out vertically, should be left in benches to prevent the washing down of the bank.

In North Carolina, where most of the kaolin deposits are vein formations whose depth is comparatively great as compared with their width, the method adopted is to sink a circular pit in the kaolin about 25 feet in diameter. As the pit proceeds in depth it is lined with crib work of wood, and this lining is extended to the full depth of the pit, which varies from 50 to 100 or even 120 feet. When the bottom of the kaolin has been reached the filling in of the pit is begun, the crib work removed from the bottom upward as the filling proceeds. If there is any overburden this is used for filling in the pit, and as soon as pit is worked out a new one can be sunk in the same manner right next to it. In this way the whole vein is worked out, and if the deposit is large, several pits may be sunk at the same time to increase the output of the mine.*

Hydraulic mining has been tried with some success in some very sandy loose-grained kaolins, but it would not work in any of the deposits in Alabama, which the writer has thus far examined. The method to state it briefly, consists in washing the clay down into the bottom of the pit whence it is sucked up by means of a pump and discharged into washing trough from the conveying pipe, it being sometimes necessary to have a scraper to stir or loosen up the clay in order to permit its being drawn up more easily. This is a cheap and rapid methed where it can be employed, but most kaolins are too dense and not sandy enough to allow of its being used.

THE WASHING OF KAOLINS.

As has already been stated, most kaolins have to be washed before shipment, and one of two methods may be employed, i. e. washing in tanks or troughing. With the first method or that of washing in tanks, the kaolin is thrown into large circular tubs filled with water, in which it is stirred up by means of revolving arms and the clay lumps thereby disintegrated. By this treatment the fine kaolinite particles as well as very fine grains of mica, feldspar, and quartz remain

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*H. Ries, Clay Deposits and Clay Industry in North Carolina Bulletin No. 13, N. C. Geol. Surv., p. 54.

suspended in the liquid while the coarser grains settle on the bottom of the tank. The water with the suspended clay is then drawn off to the settling tanks.

A modification of this consists in the use of a large cylinder closed at both ends and set in a horizontal position; through this cylinder passes an axis with iron arms, the revolution of the latter serving to break up the clay, which is discharged through a hopper at the top. A current of water passes through the cylinder and carries the fine clay particles with it while the coarse ones are left behind in the machine. The speed of the current has to be regulated by experiment, for if too much water is used coarse material will be washed out of the cylinder, and conversely, if the current is too slow the clay will not yield a sufficient percentage of washed product. One objection to this apparatus is that it has to be stopped from time to time to remove the coarse sand from the machine.

The method most commonly used at the present day for washing kaolin, is by troughing and its general detail is as follows:

As the kaolin comes from the mine it is generally discharged into a log washer, which consists of a semicylindrical trough in which there revolves a horizontal axis, bearing short arms. The action of these arms breaks up the kaolin more or less thoroughly, depending on its density, and facilitates the subsequent washing. The stream of water directed into the log washer sweeps the kaolin and most of the sand into the washing trough, which is about 15 inches wide and 12 inches deep. It may be wider and deeper if the kaolin is very sandy; in fact it should be. The troughing is about 700 feet long, and to utilize the space thoroughly, it is broken up into sections, 50 feet to each is a good length, these being arranged paralleled, and connected at the ends, so that the water, with suspended clay, follows a zigzag course.

This troughing has a slight pitch which is commonly about one inch in twenty feet, but the amount of pitch depends upon the kaolin, and whether the sand which it contains is fine or coarse. If the kaolin is very fine, and settles slowly, the pitch need not be so great and vice versa. A large quantity of very coarse sand in the kaolin is a nuisance as it clogs up the log washer, and upper end of the trough more quickly and causes so much more labor to keep them clean. As it is, considerable sand settles there, and, to keep the trough clear, sand wheels are used. These are wooden wheels bearing a number of iron scoops on their periphery, as the wheels revolve these scoops catch up a portion of the sand which has settled in the trough, and as each scoop reaches the upper limit of its turn on the wheel, it, by its inverted position, drops the sand outside of the trough. These sand wheels are an aid, but it is often necessary, in addition, to keep a man shoveling the sand from the trough.

If the sand is finer it is not dropped so quickly, but is distributed more evenly along the trough, and does not clog it up so fast.

The zigzag arrangement of the troughing has been objected to by some, as it produces irregularities in the current causing the sand to bank up in the corners at the bends, and also at certain points along the sides of the troughing.*

The effect of this is to narrow the channel, and consequently to increase the velocity of the current, thereby causing the fine sand to be carried still further to-

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*E. Hotop, Thonindustrie Zeitung, 1893.

ward the settling tank. This difficulty, which is not often a serious one, has been obviated either by having the troughing longer or by allowing the water and suspended clay, as they come from the log washer, to pass through a section of straight trough, and from this into another one, of the same depth but five or six times the width, and divided by several longitudinal partitions. The water and the clay then pass into a third section, twice as wide as the second, and divided by twice the number of longitudinal divisions.

By this means the water moves only in a straight course, but as it is being continually spread out over a wider space it flows with an ever decreasing velocity.

By the time the water has reached the end of the troughing, nearly all of the coarse grains have been dropped and the water is ready to be led into the settling vats, but as a further and necessary precaution it is discharged on to a screen of one hundred meshes to the linear inch, the object of this being to remove any coarse particles that might possibly remain, and also to eliminate sticks and other bits of floating dirt that are sure to find their way in.

Two kinds of screens can be used, (1) stationary, and (2) revolving.

The stationary screen is simply a frame with a copper cloth and set at a slight angle. The water and suspended kaolin fall on the screen, and pass through. A slight improvement is to have two or three screens which overlap each other so that whatever does not get through the first will fall on the second. If the vegetable matter and sticks are allowed to accumulate, they stop up the screen, and prevent the kaolin from running through, consequently the stationary screens have to be closely watched.

The revolving screens are far better for they are self cleaning. Such screens are barrel shaped, and the water, with the kaolin in suspension, is discharged into the interior and passes outward through the screen cloth. As the screen revolves, the dirt caught is carried upwards and finally drops; but instead of falling down upon the other side of the screen, it falls upon a board, which diverts it out upon the ground.

The settling tanks, into which the kaolin and the water are discharged, may be and often are about eight feet wide by four feet deep, and fifty or more feet long. As soon as one is filled the water is diverted into another.

The larger a tank, the longer will it take to fill it, and allow the kaolin to settle, and delays due to this cause them to be expensive, especially when the market takes the output of washed kaolin as soon as it is ready.

Small tanks have the advantage of permitting the slip to dry more quickly, especially when the layer of clay is not very thick, and furthermore a small pit also takes less time to fill and empty, but one disadvantage urged against a number of small tanks is that a thorougly average product is not obtained owing to the thin layer of settlings and the small amount in each. In addition to this a series of small tanks requires considerable room.

The advantages claimed for large tanks are that the clay can be discharged into any one for a considrable period, and, if the clay deposit varies in character, the different grades get into one tank and a better average is thereby obtained.

If the kaolin settles too slowly, alum is sometimes added to the water to hasten the deposition. When the kaolin is settled, most of the clear water is drawn off, and the cream like mass of kaolin and water in the bottom of the vat is drawn off by slip pumps and forced by these into the presses.

The presses consist simply of flat iron or wooden frames between which are flat canvas bags. These bags are connected by nipples with a supply tube from the slip pumps, and by means of the pressure from the pumps nearly all of the water is forced out of the kaolin and through the canvass.

When all of the water possible, is squeezed out the press is opened and the sheets of semi-dry kaolin are taken out. It is then dried either on racks in the open air or in a heated room.

As for every ton of crude kaolin usually only about two-fifths or one-fourth of a ton of washed kaolin is obtained, it is desirable to have the washing plant at the mines, for it avoids the hauling of 60 to 70 per cent. of useless sand which has to be washed out before the kaolin can be used or even placed on the market.

II.

GEOLOGICAL RELATIONS OF THE CLAYS OF ALABAMA,

By Eugene A. Smith, Ph. D.

The basis of all clays is kaolinite, the hydrated silicate of alumina resulting from the chemical decomposition of alumina bearing minerals which occur as essential constituents of igneous rocks. In this decomposition, as Dr. Ries has shown, the soluble constituents are leached out while the kaolinite remains behind as an insoluble residuum, more or less mixed with the other insoluble matters of the original minerals.

In this form the clay might be called a chemical clay, since it is the direct result of a chemical decomposition, having undergone no further modification by being taken up, transported and redeposited.

There is another form of residual clay which may be distinguished from the above, and that is the clay resulting from the decomposition of impure limestone. Naturally this variety is usually less free from foreign matters than the other.

These residual clays taken up and redeposited by running waters are incorporated in the stratified deposits of any later age.

The clay deposits of the different geological formations of Alabama have each its well marked peculiarities, and the geological formations are clearly defined, so that an account of the geological relations of these clays becomes a guide at once to the several varieties, and to their geographical distribution.

ARCHAEAN AND ALGONKIAN.

These two formations include in Alabama all the crystalline rocks of both igneous and sedimentary origin. It is generally acknowledged that kaolinite, which is the basis of all clays, has its origin in the decomposition of the minerals composing the igneous rocks, the chief kaolinite producing mineral being feldspar. It is. therefore, in the area of our crystalline or metamorphic rocks that we are to look for the original deposits of kaolinite. More especially, it is the granites, the *pegmatites or graphic granites,* that occur the largest proportion of feldspar, and consequently yield the largest proportion of kaolinite, and of the granites, the*pegmatites* or *graphic granites,* occurring in veins which traverse the other crystalline rock, are by far the most important in this respect.

The clays occurring in this form have been spoken of by Dr. Ries as vein clays, and they are, as a rule, very slightly plastic, for the reason that they have not been subjected to the comminuting processes necessary to develop the highest degree of plasticity.

A belt of mica schists with frequent veins of pegmatite, extends from Cleburne county and adjacent parts of Randolph, through Clay and Coosa into Chilton county, and in numerous places, the decay of the granite veins has given rise to the formation of deposits of kaolinite. The other two constituents of these granites, viz., quartz and mica, occur like the feldspars in large masses, and thus the places which produce mica in large sheets are at the same time the places where the kaolinite is to be found. Below a certain depth from the surface the feldspar of these granitic veins has escaped the action of the atmosphere, and is in its original form, while nearer the surface it has generally been converted into kaolinite. It is evident that in all these primary or original deposits the kaolinites mixed with the other and less destructible constituents of the granite, viz., the quartz and the mica, and by consequence all the kaolinite from such original deposits must be washed to free it from these substances. When the granite or granitic rock contains comparatively little of iron-bearing minerals the resulting kaolinite will be correspondingly free from iron stain and of pure white color, and thus suitable for the manufacture of the finer grades of stone ware or china.

All the important deposits of this kind are, at the present time, at a distance from any railroad, and none of them have been developed in a commercial way. We have at hand very few analyses and tests made of these kaolinites. A material of this kind from near Louina in Randolph county was analyzed many years ago by Dr. Mallett for Prof. Tuomey, with the following result:

Analysis of Kaolinite from Louina, Randolph Co.

Silica	37.29
Alumina	31.92
Ferric Oxide	trace
Potash, Lime and Magnesia	0.72
Water	15.09
Undecomposed Mineral	14.28

Prof. Tuomey remarks upon the absence of iron in this kaolinite as most favorable to its use in making fine porcelain ware, and he predicts that when Randolph county has communication by railroad with the outside world, the occurrence of porcelain clay in the county will become a matter of economic importance.

These pegmatite veins with their mica and kaolinite, are very numerous in the upper half of Randolph county, and also in the adjacent parts of Cleburne and Clay, and test pits have been sunk in hundreds of places to show up both the kaolinite and the mica. Dr. Caldwell of the Elyton Land Company, had this kaolinite thoroughly tested both as to its suitability for the manufacture of porcelain ware and as to its refractory character. The pottery ware made from it came in competition with the best pottery wares in America and took a prize at the Art Institute Fair in Philadelphia, in December, 1890. Brick made from it also was subjected to the highest temperature of the furance and was declared practically infusible. These deposits lie near Milner, Pinetucky, Micaville, in Randolph, and near Stone Hill, Mr. Jas. Denman's and other places in Cleburne. The same belt extends southwestward through Clay and Coosa into Chilton, and has been tested at various places along this line.

In this region of the crystalline rocks, one may everywhere observe the gradual transition from the solid rock through decayed schists into complete soil, which is generally a clayey loam, more or less stained wih iron. A reddish clay is thus seen to be a part of the residual matters left by the general decay of the rocks of this section, but this clay is, as a rule, so much mixed with quartz, mica, fragments of undecomposed rock, that it can serve very seldom for anything more than material for the manufacture of building brick. Residual clays of this character are of universal occurrence throughout the region of our crystalline rocks.

It is not difficult to understand how under certain conditions, the finer portions of these residual clays may be taken in suspension in running waters and redeposited at greater or less distances from their place of origin in depressions, or along slopes. In this way are often formed secondary deposits of pretty fair plastic clays, sometimes mixed with sand in proportion to serve well as material for good building brick. An illustration of this may be cited near Wedowee in Randolph county, and there are many instances where the residual clays of the country as well as these redeposited masses are utilized both for the manufacture of buildings brick of excellent quality, and for pottery purposes.

CAMBRIAN AND SILURIAN FORMATIONS.

In these formations, the clay deposits are either the residual clays left from the decomposition generally of the great limestone formations of the Cambrian and Silurian, or concentrations of these residual clays by redeposition in sink holes, ponds, and depressions; or the accumulation through sedimentary action ,in the depressions of these later formations, of the chemical or vein clays of the Archaean.

The two great limestones, above mentioned, are rarely pure but are mixed with chert or other form of siliceous matters, with iron, and with clay. Upon their decay under the action of the atmospheric agencies, these insoluble matters are left in the form generally of reddish loam or clay capped with cherty fragments, and impregnated with iron.

Such residual clays are extensively used in all our valley regions for the manufacture of ordinary building brick, for which they are very well adapted, the brick being very durable, but not very sightly, since they are likely to be spotted where the clay contains more iron than the average. Occasionally, however, we find as result of subsequent rearrangement by leaching, concretionary action, or the like, these residual matters differentiated from each other in a most remarkable way, so that beds of nearly pure white clay lie alongside of beds of brown iron ore, itself remarkably free from either clay or chert. The most notable of such instances is at Rock Run where the bed of white kaolin, analysis of which is given in the body of this report, No. A. S., forms one of the walls of a bank of limonite which has for years furnished ore to the furance. In close juxtaposition to the ore and kaolin, here mentioned, is one of the beds of bauxite for which this region is well known. Kaolin beds of this residual nature are known in many other parts of the State, resting upon the Cambrian and Silurian limestones. Near Jacksonville, in Calhoun county, at Tampa in the same county, and in numerous other localities of similar nature, are limited beds of kaolin, none of which, however, have as yet been developed or worked.

The following clays described below may be assigned to these formations; the china clays, No. 190, from near Gadsen and No. 205 from Kymulga; the fire clays, No. 191 from Peaceburg in Calhoun county and No. 127 from Oxanna in the same county; the stoneware clays, No. 204 from Blount county and No. 192 from near Rock Run.

In most of the large limonite banks of the valley regions, these deposits of pure clay occur, usually known as clay horses, some of them are undoubtedly of sufficient extent to be of commercial value. Many references to these may be found in the Report on the Valley Regions.

While none of these clay deposits have as yet found a market, it may be well for the sake of completeness to give a few details concerning such as have been recorded. The references to the pages of the report on the Valley Regions, Part II, are also added.

In connection with beds of limonite in S. 31, T. 24, R. 11 E., in *Bibb county,* mention is made of the fact that the ore lies imbedded in clay of red or yellowish red color, with streaks of a white clay (p. 495.)

In Talladega county, in the flatwoods, lying along the line of the Columbus & Western Railroad, in the southeast corner of S. 2, T. 21, R. 3 E., a white plastic clay which is said to have been penetrated to a depth of 35 feet, is reported to have been struck in a well. (p. 606.) In the same county in S. 19, T. 19, R.5 E., in the Charlton limonite bank there is a large "horse" of white clay, extensive deposits of white clay are noticed in connection with other limonite banks in the immediate vicinity. (p. 616.)

In *Calhoun county,* in T. 15, R. 8 E., and in Sections 21 and 23, there are many diggings in beds of limonite, and in most of them are "horses" of white clay, (p. 702). Again in T. 14, R. 8 E., in the same county, near Tampa, on land belonging to A. H. Tullis, Section 6, in the red residual clays derived from the disintegration of the limestones of the county, along with barite and limonite in pockets, are found some deposits of kaolin of white color and considerable thickness, up to 10 feet. In Section 5 of same township and range, the kaolin is exposedd in a cut of the East and West Alabama Railroad where it is 10 feet thick. (p. 715.)

In *Cherokee county*, to the northward of the line of the Southern Railroad in Sections 1 and 2 of T. 12, R. 11, E., there are many banks of limonite which have been extensively worked, and in some of them beds or "horses" of white clay have been exposed. One of these in the Clay limonite bank, in Section 2, the clay deposit is of great extent and several car loads have been taken from it and shipped to Chattanooga for manufacturing into fire brick. A similar white clay occurs in the Hickory Tree bank in Section 1, (p. 759.) The occurrence of the clay in the Dyke limonite bank, near Rock Run, is described on page 777. This is the kaolin whose analysis is given below under the number A. S. In the Washer bauxite band in S. 35, T. 12, R. 11 E., near Rock Run, and in the Warwhoop and other bauxite banks of the same vicinity, white clay and halloysite are of common occurrence. Some of these clays should be utilized.

Some details concerning them are to be found in the Valley Regions report, pages 780 to 789.

In the limonite banks to the eastward of Tecumseh furance in the same county, in T. 12, R. 12, E., clay *"horses"* are everywhere found separating the pockets of limonite, pages 792 and 793.

Accumulations of good plastic clay, which have evidently been deposited in the depressions of the limestone or in ponds, are not uncommon in the area of the great limestone formations. One such near Oxford in Calhoun county, is utilized by the Dixie Tile and Pottery Company. Analysis and physical tests of this clay are given in the body of this report.

Of less purity on account of mixtures of sand, etc., similar deposits are numerous, and utilized in places, as, for example, the brick clay at DeArmanville in the Choccolocco valley.

SUB-CARBONIFEROUS FORMATION.

In the Sub-carboniferous formation of Wills' Valley is found the best known deposit of pure white clay of this section.

This clay occurs chiefly in the lower strata of the formation, generally very close above the Devonian Black Shale. The deposits which have, up to the present time, been pretty well proven, are to be found in the upper or northeastern end of Wills' Valley, near the Georgia line, and on both sides of the valley. The most important of them, however, occur on the eastern side of the valley. They have been described somewhat in detail by McCalley in Part II of his Valley Regions report, pages 175 to 182, from which the following details are compiled:

The Red Mountain ridges, made up of the strata of the Clinton, Devonian (Black Shale), and Sub-carboniferous formations, occur here as elsewhere in the State, on both sides of the valley. The ridge on the western side is, in general, lower and less continuous than that on the eastern side. The clay occurs in the lower strata of the Sub-carboniferous, not far above the Black Shale, and it has been "prospected" and found to be present in the ridges on both sides of the valley for some ten or twelve miles from the State line southward.

In the northwest corner of S. 3, T. 6, R. 9 E., on the west side of the valley, a test pit exposes the following section:

Section on west side of Wills' Valley, DeKalb Co.

Chert ledge weathered into a sandy rock of yellow color	8 to 12 inches.
Strata hidden by debris	2 to 3 feet.
White clay, without grit, in places like halloysite	3 feet.
Bluish colored clay	3 feet,
Strata not exposed	25 to 30 feet.
Devonian Black Shale	

The white clay occurrs in many places in this vicinity, and is called *chalk* by the people.

On the eastern side of the valley, the Red Mountain ridge, as stated above, is more prominent and continuous than on the west. Near the State line, about Eureka station and thence southwestward for a couple of miles, the clays have been tested and in many places worked. They have a thickness aggregating about 40 feet, but are said to thicken up occasionally to 180 to 200 feet, of which as much as 60 feet is a fine white clay suitable for the manufactory of stone ware. Some of the clay is shipped from here to the potteries at Trenton N. J., and some of it goes to Chattanooga, Tenn. *The Franklin (Ohio) Company Mines* are situated in the northern corner of S. 34, T. 4, R. 10 E. The clay is won by surface diggings, slopes, and tunnels, according to locality.

The following section is obtained along the wagon road through the surface diggings and will give a fairly correct idea of the occurrence.

Section at Franklin Company's Mines, DeKalb Co.

Alternations of chert layers, 4 to 18 inches thick, with fine sharp siliceous powder of white and yellow color	12 feet.
Chert of light yellow color, interlaminated with thin streaks of clay	12 feet.
Clay, mostly of yellow color, but with seams of white clay	10 feet.
Alternations of chert in layers of 2 to 8 inches thickness with clay seams 18 inches in thickness	4 feet.
Alternations of chert in layers 2 to 6 inches thick with white clay in irregular seams 6 to 12 inches thick	18 feet.
Clay, very gritty, of white color and chalky appearance	10 feet.
Clay and shale, the clay white and gritty, the shale green	10 feet.
Devonian Black Shale	

In these mines in the upper twenty feet the clay is more siliceous than in the lower twenty feet. The siliceous clay is better suited for making fire brick, while the plastic clay is a potter's clay, commanding a good price. The chert which is interstratified with the clay is also of value in the manufacture of stoneware.

In the N. E. ¼ of the S. E. ¼ of S. 4, T. 5, R. 10 E. are the *Montague Clay Mines,* worked by a tunnel on the southeastern side of the ridge. The clay is about thirty feet in thickness, some of it having a brown coloration, due to organic matter. It is quite uniform in composition for a distance for at least a mile in a northeast and southwest direction, is quite free from stains of iron but perhaps less plastic than the clay from some of the other localities near by. Most of the clay here mined goes to Chattanooga for the manufacture of fire brick. Two analyses of the clay from these mines are given by Dr. Ries under the numbers 116 and 117 and they are classed by him as fire clays.

Further southwest, along the ridge, we find other occurrences of the clay as in the S.W. ¼ of the N. W. ¼ of S. 12, T. 6, R. 9 E., where there is an old opening on a clay bed, which shows some four feet of clay. Still further southwestward in the N. W. ¼ of the S. E. ¼ of S. 15, T. 6. R. 9 E., there are numerous surface diggings, and tunnels in a clay bed thirty feet or more in thickness. Some of the clay of this deposit is of most beautiful quality, and especially well suited to the manufacture of the finest stone ware. A set of china ware, 700 pieces, made from this clay took a premium at the New Orleans Cotton Exposition.

In places the clay has streaks and stains, due to iron, and in other places it has a dark gray color, due to the presence of organic matter, which does not prevent its burning to a white color. Much of the clay is adapted to the manufacture of fire brick as shown by the analyses of a sample collected by Dr. Ries, number 119. Analysis, number 214, shows the quality of the purer and whiter variety.

The clay deposits extend to within two or three feet of the Devonian Black Shale, thus fixing the occurrence at the base of the Subcarboniferous formation.

Beds of potter's clay of this formation have also been noted at other localities, among them one in the railroad cut just north of Stevens' switch on the A. G. S. R. R., and another in Calhoun county in S. 19, T. 15, R. 6 E.*

Hard white clay, like halloysite in appearance, has also been noticed at points in the Tennesseee valley, near Stevenson, and it is quite probable that search in that valley would be rewarded by the finding of deposits of the clay of commercial importance.

COAL MEASURES.

In some parts of the coal fields, the under clays of the seams of coal have been utilized in the manufactory of pottery, as at Jugtown, near Sterritt, in St. Clair county; at Fort Payne and Rodentown, in DeKalb; at Vance's Station, in Tuscaloosa county; at Summit, in Blount county, and at Arab, in Marshall county. In all these places the clay is manufactured into jugs, flower pots and similar articles, while at Fort Payne it is also used in the manufacture of fire brick.

The shales of this formation are also utilized in some parts of the State, notably at Coaldale, where they are made into vitrified brick for paving purposes. At the Graves Coal Mine, near Birmingham, occur two bodies of shale, which have been analyzed and

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*Valley Regions, Part II., pages 441 and 741.

otherwise tested for this report, and the results of these tests are to be found below, numbers 170 and 171.

Dr. Ries has tested also the Carboniferous shales from near Pearce's Mill, in Marion county, and finds them admirably suited for the manufacture of pressed brick and with a mixture of a more plastic clay suitable for the manufacture of terra-cotta (No. 3.) Up to the present time none of the clays from the Coal Measures have been found suitable for use in the manufacture of high grades of fire brick, but this may be due to the circumstance that very few of these clays have beeen examined. Of shales suitable for making vitrified brick, there is the greatest abundance.

CRETACEOUS FORMATION.

In many respects the most important formation of Alabama in respect of its clays, is the lowermost division of the Cretaceous, which we have called the Tuscaloosa. The strata composing this formation are prevalently yellowish and grayish sands, but subordinated to these are pink and light purple sands, thinly laminated, dark gray clays holding many well preserved leaf impressions, and great lenses of massive clays varying in quality from almost pure white burning clays to dark purple and mottled clays high in iron.

This formation occupies a belt of country extending from the northwestern corner of the State, around the edges of the Paleozoic formations to the Georgia state line at Columbus. Its greatest width is at the north-western boundary of the State, where it covers an area in Alabama thirty or forty miles wide and about the same width in Mississippi.

From here towards the southeast the breadth of the belt gradually diminishes, till at Wetumpka and thence eastward to the State line, it forms the surface along a belt of only a few miles width.

To the eastward of the Alabama river, the proportion of clay to the rest of the strata is less than in the other direction, and at the same time the clays themselves are as a rule more sandy. But from the Alabama river northwestward, in the gullies, ravines, and railroad cuts, there are many exposures of these beds, exhibiting sections of clay beds from six to forty or fifty feet in thickness, and of varying degrees of purity. In a general way we may say that the purer clays, resmbling kaolin in composition, have as yet been found only in the northern part of this area in Fayette, Marion, Franklin and Colbert counties, and the adjoining parts of Mississippi.

In my Coastal Plain Report, published in 1894,* I have brought together many details concerning the Tuscaloosa formation in the counties of Lee, Russell, Macon, Elmore, Autauga, Chilton, Perry, Bibb, Tuscaloosa, Pickens, Lamar, Fayette, Marion, Franklin and Colbert, and the reader is referred to that book for full discussion of the formation.

In order, however, to present the clay occurrences as completely as possible I shall give extracts from the Coastal Plain Report in so far as they may be descriptive of the deposits of clay.

To these extracts are added a number of details received from a report made by Dr. George Little, who in 1891, spent several months making for the Geological Survey ,some examinations of the clays

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*Pages 307-349, 531-2, 536, 541, 545, 549 554, 556, 559.

of this formation. Dr. Little brought together a large collection of the chief varieties of these clays and from these specimens, many of the analyses found in the report below have been made.

Use is also made of manuscript notes of my own on examinations made since 1894 and of descriptions of clay occurrences in the report on the Valley Regions, Part I, by McCalley.

Inasmuch as the remarks of Dr. Eugene W. Hilgard on the clays of Missisipppi apply in general to the clays of this State which lie immediately adjacent to them on the east, a short extract from his Report on the Geology and Agriculture of Mississippi will not be out of place. These notes relate to the clays occurring in Townships 4, 5 and 6 in Tishomingo county, Mississippi, and were published in Dr. Hilgard's Report on the Geology and Agriculture of Mississippi, 1860.

"A large deposit of white clay of great purity, however, occurs in Tishomingo c ounty, chiefly in the southern portion of the territory of the Carboniferous formation, following very nearly its western outline. It there forms a regular stratum of considerable extent, which ,in one locality at least, was found to be more than 30 feet in thickness. The bed attains its best development, so far as the quality of the material is concerned, in the northern portion of Township 5 and in Township 4, Range 11 east, where it is about 30 feet underground in the uplands, though at times appearing in limited outcrops on the banks of the streams. Northeastward and southwestward from the regions mentioned, the bed also occurs but changed in character, at least near the surface, to a white gritty hardpan, or clays of various colors and of much less purity. It forms the lowest visible portion of the Orange Sand formation, and is almost invariably overlaid by strata of pebbles and pudding stone, which in their turn are sometimes overlaid by common orange-colored sand.

The most southerly exposure of these beds, known to me, occurs on a small branch of McDouglas' Mill creek, in Sections 5, 4, and 9, Township 6, Range 10, east, near Mr. Pannel's place. For more than a mile along this branch there are exposures in which about 20 feet of a whitish mass, varying from a fine clayey sand to a white plastic clay, appears overlaid by thick beds (20 to 40 feet) of ferruginous pebble conglomerate; the latter in its turn being overlaid by the common ferruginous sand and brown sandstone on the hilltops. Similar outcrops appear in the neighborhood of Mr. Aleck Peden's place on Sections 3 and 27 ,Township 5, Range 10 east, northeast of Pannel's Here also a white stratum of which only a few feet are exhibited is overlaid by pebble conglomerate, and this by the common Orange Sand. The white mass varies from white plastic clay to fine grained aluminous sandstone; its upper layers are sometimes composed of a singular conglomerated mass, consisting of small, white quartz pebbles imbedded in pure white pipeclay. In both localities, copious springs of pure water are shed by the impervious clay strata. At Mr. Peden's, there is a fine bold chalybeate spring which seems, however, to derive its mineral ingredients (sulphates of iron and magnesia and common salt) from the adjacent Carboniferous strata rather than from those of the Orange Sand. In either of the localities mentioned, materials suited for fine pottery, or queenware, might be obtained.

Thence northwest, the stratum is not often found outcropping, but, as had been stated, 20 to 30 feet below the surface of the uplands; the country being but slightly undulating. At Dr. Clingscale's, Section 8, Township 5, Range 11 east, the clay stratum was struck at the depth of about 30 feet beneath sand and pebbles; it was dug into, without being passed through, for nearly 30 feet more, no water being obtained from below, but dripping in above from the base of the pervious strata. The whiteness and plasticity of the material seems to increase with the depth. The portion of what was dug out of the well in question, had already been removed at the time of my visit, having been used for various economical purposes as, chalk, whitewash, and "Lily White". The specimens examined were, therefore, rather below the average quality, and on long exposure to the air, their surface shows some yellowish spots. I found nevertheless, that in baking at a high heat they yielded a biscuit of greater whiteness than their natural color when fresh; and that fine splinters, exposed for ten minutes to the highest heat of the mouth blowpipe, retained their shape perfectly while reduced to a semi-transparent frit. A quantitative analysis of the clay from Clingscale's well gave the following results:

White Pipe Clay from Clingscale's.

Insoluble matter	90.877
Lime	0.140
Magnesia	trace
Peroxide of iron	0.126
Alumina	2 214
Water	6.930
	99.864

This analysis (which was made solely for the purpose of ascertaining the ingredients foreign to the clay proper) proves the singular fact that this clay, though occurring in a formation characterized by the large amount of iron it commonly bears, contains a remarkably small amount of that substance, which, together with minute porportions of lime and magnesia, explains its infusibility.

The two most important practical purposes which the materials occurring in the deposits just described will serve, are the manufacture of fine queenware and that of fire proof brick. (Not porcelain. Kaolin or porcelain earth contains, besides the white clay, a certain amount of undecomposed feldspar, which imparts to it its property of being semi-fused at the temperature of the porcelain kiln. The same property might be imparted to the white clay in question, by the artificial admixture of ground feldspar, but it could not thus compete with the naturel kaolin of Alabama).

As for the queenware, the plasticity of the material leaves nothing to be desired; and since the amount of siliceous matter varies greatly in different layers, there could be no difficulty about givng to the mass the precise degree of meagerness which may be found most advantageous, by mixing the several successive layers. The same may be said with reference to the manufacture of fire brick (to which these materials are admirably adapted), which would probably, at the present time, be the most feasible and most profitable manner in which the beds could be made available. The manufacture of fire brick differs from that of ordinary brick in this, that it requires more care, both in working the clay and in moulding the brick. Beyond their fireproof quality, it is demanded of fire brick *that their shape be perfect, their mass uniform and without flaws in the interior;* also that they shall be liable to *the least possible shrinkage* in a high heat. The latter quality is imparted to them by a considerable mixture of either sand or ground fire brick to the fireproof clay, which itself ought to be thoroughly seasoned before, and then well worked up with such additions of the above materials as may be required. In judging of the amount of sand or ground brick to be added, it is to be observed, as a rule, to add as much as may be consistent with the proper firmness of the burnt brick and with convenient moulding. The latter process ought to be performed, as in the manufacture of pressed brick, whenever a first-class article is aimed at, for it is only thus that external and internal flaws are entirely avoided. In some localities materials may be probably found which require no further admixture—the strongly siliceous varieties of the clay; but whenever sand or burnt clay is added to the mass, care should be had that it be free from iron, which would seriously impair the fireproof qualities of the clay. None but white sand should be used. For the rest, they may be burnt in kilns like common brick."

RUSSELL AND MACON COUNTIES.

Within the limits of Girard and Phœnix City, opposite Columbus, and in the hills to the west of Girard, are many exposures of the Tuscaloosa strata, aggregating some 200 feet in thickness. These are composed mainly of sands, but there are numerous beds of white, gray and purple or mottled clays interstratified with the sands. The small stream which flows through Girard exposes a number of these clay beds, and others are to be seen in the hills to the west of the town. The materials for the manufacture of drain pipe, vitrified brick, pressed brick etc., are here in abundance.

These clays are to be seen at intervals along the road leading toward Montgomery, e. g., near Marvyn, Crawford and Society Hill, the prevailing variety being the mottled red or purple clay. Northwest of Society Hill these clays occur as far as Farrell's Mill, in Macon county.

Near Cowles' Station, at the ferry across the Tallapoosa river, purple clays, three feet in thickness, show in the river bank, and a short distance further down the river at the site of Old Fort Decatur, a fine section of the Tuscaloosa beds, including many beds of clay from one foot thickness and upwards is exposed.*

ELMORE AND AUTAUGA COUNTIES.

In the vicinity of Old Coosada town, along the banks of the river, about Robinson Springs and Edgewood, there are many occurrences of the clays of this formation, analyses of which have been made by Dr. Ries, and the results given below in the body of the report. About Edgewood there are several potteries and one ochre mine using the materials of the Tuscaloosa formation. McLean, Vaughn and Boggs have potteries here, and Pressley has one further west.

At Chalk Bluff, near Edgewood, there is a very characteristic section exposed in an ancient bluff of the river, now at a distance of more than a mile from that stream. The section is as follows:

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*Coastal Plain Report, p. 554, 556.

Section at Chalk Bluff, Elmore County.

1.	Layette red loam and pebbles...	15 feet
2.	Gray and yellow sandy clays, in distinct but irregular layers	6 "
3.	White clay, 3 feet graduating downwards into yellow ochreous clay, 3 feet	6 "
4.	Gray plastic clay blue when wet, and exceedingly tough and sticky; full of vegetable remains, flattened and bituminized	10 "

Two samples of this clay (Nos. 101 and 122) have been tested and analyzed by Dr. Ries (see below under the head of Pottery Clays and Brick Clays), where a section of this bluff is given, differing slightly from the above. This is not to be wondered at, since the stratification is very irregular, and no two sections, twenty feet apart, are idential.

Along the line of the Mobile and Ohio Ry., in Autagua, and on most of the pubilc roads leading from Prattville north and northwest, there are exposures of Tuscaloosa strata, consisting of sands and clays, the former predominating. In the western or northwestern part of the county, near Vineton, many instructive sections of the Tuscaloosa beds are to be seen. Some of these sections include beds of clay, which are of interest in our present work.

Section, near Col. J. W. Lapsley's place, Vineton.

1.	Stratified clays of white, pink, and purple colors, interlaminated with thin sheets of yellow sands; the lower part of this bed has a larger proportion of sand	10½ feet
2.	Gray laminated clay with partings of purple sands	5 "
3.	Yellowish white laminated clays, with purple and other bright colors on the dividing planes, 5 feet showing, but the same beds appear to continue down the hill for at least ten feet further	15 "

Section No. 2, near the preceding.

1.	Yellowish sands, beautifully cross-bedded....	4 feet
2.	White and pink clays, interbedded with yellow sands	10 "

Section No. 3, same locality.

1.	Purple clays interbedded with reddish sands..	6 feet
2.	Mottled (red and yellow) sandy clays, partly obscured by overlying pebbles and sands......	12 "
3.	Red sands with small lenticular bits of yellow clay......	5 "
4.	White and yellow laminated clays	6 to 8 "

At the bridge over Mulberry, near Vineton, the following strata are shown in the banks of the creek:

Section on Mulberry Creek, near Vineton.

1.	Mottled purple clays, similar to those at Steele's Bluff on Warrior River	5 feet
2.	Yellow cross sandy beds	2 "
3.	Mottled clays sandy below	5 "
4.	Grayish white micaceous sands, with irregular patches of red and yellow colors; to water's edge	4 "

BIBB COUNTY.

From Vineton up to Randolph very little of the strata of the Tuscaloosa formation can be seen until within three miles of the latter place, where dark purplish gray clays are to be encountered. Between Randolph and Centerville, along the public road, and at many points along the railroad from Mapleville to Centerville, there are occurrences of the massive clays of this formation. These clays have given much trouble and caused much expense to the railroad, from the fact that when softened by the winter rains they squeeze out into the railroad cuts, filling them up and overflowing the track. Where the clays from the cuts are used to make embankments, they are equally troublesome, as they are continually giving way. We have no accurate notes of the sections exposed in the railroad cuts but the public road from Randolph to Centerville has been somewhat closely examined. At Soap Hill there is a typical section as follows:

Soap Hill, 7 miles East of Centerville.

1.	Purple and mottled clays at summit of hill...	5 feet
2.	Clayey sands in several ledges	10 "
3.	Cross bedded yellowish and whitish sands, traversed at intervals by ledges of sandstone formed by the induration of the cross-bedded sands	30 "
4.	Laminated gray clays with partings of sand..	10 "
5.	Alternations of laminated gray clays with cross-bedded sands in beds of 12 to 18 inches thickness	40 "
6.	Yellowish cross-bedded sands with clay partings	20 "
7.	Laminated gray sandy clays containing a few leaf impressions	10 "
8.	Grayish white sands	8 "

On the same road in the eastern part of the town of Centerville, on the School House Hill, there may be seen some fifteen feet thickness of purple and yellow clays.

The same beds show along the Selma road, south of Centerville, at many points. Sections are given in the Coastal Plain Report, pages 336 and 338. To the southwest of Centerville also, in townships 21 and 22, ranges 7 and 8, many of the ridges are composed of purple clays eight or ten feet in thickness, resting on four to six feet of gray clays.*

On the road to Tuscaloosa the clays show about half way between Centerville and Scottsville.

Along the line of the Alabama Great Southern Railroad in this county, there are many exposures of the Tuscaloosa clays, e .g. at Bibbville, where they have been utilized for many years in the manufacture of semi-refractory fire bricks for grates, etc. A great

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*Costal Plain Report, page 338.

deal of the material is shipped now to Bessemer, where it is worked up into fire brick. Further north, near Woodstock again are rather extensive diggings on the line of the Birmingham Mineral Railroad, from which the clay is shipped to Bessemer and used as above indicated.

Dr. Ries has investigated the clays from both of these localities, and his results are given below in the body of the report, under No. 112 for the Bibbville's specimen, and No. 111 for that from Woodstock. He classes them with the fire clays. Another specimen from Woodstock, classed by Dr. Ries as brick clay, has been tested, (No. 126, A. Stevens).

TUSCALOOSA GOUNTY.

The utilization of the clays of this formation was begun in Tuscaloosa county by Daniel Cribbs in the year 1829. He was the pioneer, though it is said that W. D. Preston had a pottery in Autauga county in 1828. C. K. Oliver has had a pottery in this county since 1856. Peter Cribbs, in Lamar county, carried on the business for twenty-five years. He was the brother of Daniel, whose son, Harvey H. Cribbs, has for many years been more or less engaged in working the clays along Cribbs Creek, two miles south of Tuscaloosa, and later four miles east of town on the Alabama Great Southern Railroad. The Lloyd family have operated several potteries in Marion county, Alabama, and Itawamba county, Mississippi, for many years. Fleming W. Cribbs, a son of Peter, has now a pottery at the new town of Sulligent, on the K. C. M. & B. R. R.*

Within the limits of the city of Tuscaloosa there

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*Notes of Dr. George Little.

are many exposures of the clays of this formation in the gullies facing the river bottom. In one of these gullies the section is as follows:

Section in Tuscaloosa.

1.	Pebbles, sand, and red loam of the Lafayette forming the plateau on which the city of Tuscaloosa stands	15 feet
2.	Light gray, somewhat massive clays, mottled with yellow, but becoming laminated below	3 "
3.	Dark-blue, nearly black laminated clays, laminae half an inch thick, separated by thin partings of white sand. The clay contains leaf impressions	3 "
4.	Yellowish gray laminated clays, also containing impressions of variable thickness, average	2 "
5.	Strongly cross-bedded sands, yellowish to white, sharp, with a few streaks of clay irregularly distributed through it..........	20 "

At the proper depth below the surface, the clays above mentioned are encountered in most parts of the plain, though naturally the thickness of the beds and their character vary from place to place.

Eastward from the city the cuts of the A. G. S. railroad exposes these clays at numerous points. Some four miles from town they have been utilized by Mr. Harvey Cribbs in the manufacture of flower vases, jugs and similar wares. Below about twenty feet of the surface red loam and pebbles, we find at this place one to twelve feet of white clay, free from streaks; then three feet of yellow sand and a bed of blue clay of undetermined thickness.*

D. Ries' analysis and tests of the Cribbs' clays are given below under No. 1, S., where it is classed among the pottery clays.

At the Box Spring, about five miles east of Tuscaloosa, the railroad cuts expose about six or eight feet of laminated gray clays marked with purple streaks. Beyond Cottondale, nine miles from Tuscaloosa,

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*Notes of Dr. George Little.

about thirty or forty feet thickness of purple clays is seen along the hillside.

Some twelve miles east of Tuscaloosa the grayish purple clays appear in many places along the slopes of the hills. The following general section of strata in this vicinity will give a good idea of the formation:

Section 10—12 miles East of Tuscaloosa.

1.	Purple massive clays	5 feet
2.	Ferruginous sandstone crusts	6 to 8 inches
3.	Variegated clayey sands holding small pieces of purple clay	10 feet
4.	Purple clays with partings of sand	10 "
5.	Ferruginous crust	1 "
6.	Laminated gray and yellow sandy clays	6 to 8 "
7.	Lignite with pyrite nodules	2 to 6 inches
8.	Dark gray somewhat massive clays	6 to 8 "
9.	Strata obscured by debris from above	20 "
10.	Purple clay at base of hill, thickness undermined.	

Along the A. G. S. R. R. beyond Cottondale, the cuts show many varieties of materials of this formation, among them beds of purple clays, sometimes massive, sometimes laminated. Just beyond Cottondale the clays gave much trouble many years ago at what was known as the "Sliding Cut."

A mile or two beyond Vance's Station, a bed of these clays is now being worked for material to use in the manufacture of fire brick at Bessemer.

Southward from Tuscaloosa the clays are seen in most of the hills bordering Big Sandy Creek, and judging from the width of the outcrop along the hillsides there can not be less than fifty feet thickness of them.

The same clays show along the A. G. S. railroad at Hull's Station, and all that vicinity, and Dr. Ries presents an analysis, together with the physical tests, of a sample of this clay, No. B., which he classes as a refractory or fire clay.

A characteristic section of these clays exposed along the hillsides, just south of Big Sandy, where the Greensboro road passes, is given below:

Section on Big Sandy Creek, Tuscaloosa County.

1.	Purple or mottled clays, like those occurring at Steele's Bluff, on Warrior river	30 feet
2.	Light yellow sands with pebbles, also similar to those seen at Steele's and White's Bluffs	10 to 15 feet
3.	Gray, laminated clay, enclosing a lignitized tree trunk at base of hill	4 to 5 feet

Further south the materials of the Tuscaloosa formation seem to be more sandy, and the proportion of clays is small.

Along the banks of the Warrior river below Tuscaloosa, the clays show up in many places, especially in the vicinity of Saunders' Ferry.

At the Snow place, above the ferry, there are some great gullies, in which these sands and clays of the formation are exposed. In some of the clay beds many leaf impressions have been obtained, which have assisted in the determination of the geological horizon of the Tuscaloosa formation.

A short distance above the ferry, and adjoining the Snow place, there is a bluff about 140 feet high which shows the clays and other beds of this formation very clearly. The section is as follows:

Section above Saunders' Ferry, Warrior River.

1.	Massive clays of greenish and purple colors, breaking with conchoidal fracture. On drying these clays become hard and rock-like. When wet by the winter rains, they soften and slide down the slopes, covering them completely in places. Thickness	40 feet
2.	Laminated sandy clays, gray, with sand partings	5 feet
3.	Gray cross-bedded sands, with partings of clay along many of the planes of false bedding	25 feet
4.	Gray cross-bedded sands and blue micaceous sands	23 feet

At Williford's landing the purple clays show about ten feet in thickness below the second bottom, or river deposits.

At Steele's Bluff, and a few miles below, at White's Bluff, similar purple or mottled clays make about ten feet thickness of the river bluff.

Westward and northwestward of Tuscaloosa the clays appear along all the roads for many miles to the western boundary of the county, and beyond into Pickens. The clays when freshly exposed are of gray color, but undergo a series of changes in consequence of weathering, and the oxidation of the iron which they contain. First, the gray becomes specked with red, and this color gradually increases in proportion until it prevails, and the whole body of clay becomes a dark red or purple mass, with few, if any, of the fragments of the original gray color.

At John Mills', about thirteen miles from Tuscaloosa, on the Shirley Bridge road, the following section is made by Dr. Little:

Section in Tuscaloosa County.

1.	Red loam and sand (Lafayette)............	10 feet
2.	Ferruginous sandstone crust....	6 feet
3.	Blue clay (Sample No. 1)..................	6 feet
4.	Yellow sand, with indurated crust above and below........	7 feet
5.	Blue Clay (No. 2)..........	6 feet
4.	Yellow sand, with indurated crust above and	

On the Fayette Court House road the same clays show at many points, but the most promising clays along this road have been observed beyond the Tuscaloosa county line in Fayette.

The Mobile and Ohio road to the northwest of the city of Tuscaloosa exposes in many of its cuts beds of clay, which have been a source of much trouble and expense house of the filling of these cuts by the softened clay during the winter seasons. Several cuts in the vicinity of Ten Mile Cut have traversed these beds of clay. One specimen from the Ten Mile Cut has been examined by Dr. Ries, and classed among the brick clays (No. A), though, as Dr. Ries remarks, there is no reason why it should not find other uses as well.

In the near vicinity of this cut, on land formerly occupied by Mr. J. C. Bean, occur three beds of clay measuring each about five feet thickness. These have been investigated by Dr. Ries under the Nos. 118, 115 and 100. The first of these, classed as fire clay, has many points of interest, growing out of its dense burning at low temperature, and the great difference in temperature between the points of incipient fusion and vitrification, suggesting its suitability for use as a glass-pot clay. The other two clays are classed as pottery clays, and are perhaps representative of one of the most widely distributed types of the clays of this formation.

PICKENS COUNTY.

Near the line of the M. & O. road, in this county, the clays are observed from the Tuscaloosa county line to within nine miles of Columbus. In mode of occurrence and in the character of the clay these beds resemble those of Tuscaloosa, above mentioned. From Roberts' Mill on Coal Fire Creek, Dr. Little has collected a sample of white clay which has been analyzed by Dr. Ries, No. 32 S. It is classed by him among the stone-ware clays, burning to buff color, and is in many respects similar to the Cribb's clay of Tuscaloosa. West of Coal Fire Creek, and at a distance of 18 to 20 miles from Columbus, the massive reddish clays show in the hills to a thickness of 40 to 50 feet.*

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*Notes of Dr. George Little.

LAMAR COUNTY.

The strata of the Tuscaloosa formation cover the entire area of Lamar below the mantle of red loam and pebbles of the Lafayette. Among the strata are numerous beds of clay of varying degrees of purity. Dr. Little's notes, which follow below, give many details concerning them.

Along the line of the Southern (Georgia Pacific) Railroad, there are many exposures of the clays, as at Millport, where the clay shows at a thickness of four feet; beyond this at about 23 miles from Fayette Court House, the clay seems to be 10 feet thick, and near this at Fernbank, J. D. Green has a pottery. His clay is 18 feet thick, analysis of this clay is to be found in Dr. Ries' report, No. 27 S.

Along the road from Fayette Court House to Vernon, at 9 miles from the former place we have this section.

Section nine miles west of Fayette C. H., in Lamar Co.

Blue clay	6 feet
Mottled clay	20 feet
Sandy clay	4 feet

Three miles further west on the same road, this clay is some 20 feet in thickness. Within two miles of Vernon, in A. W. Nichol's well, blue clay 8 feet thick is penetrated below six feet of overlying sands.

One mile east of Vernon, at a saw mill, there is clay, white and 3 feet in thickness.

On the old military road of Gen. Jackson at a distance of 20 miles from Columbus, Miss., and about 7 or 8 miles northwest of Vernon, near Bedford P. O., are the remains of a pottery once owned by Peter Cribbs. At this place lives Captain Cribbs, a negro man with his son, Major. Captain worked for many years in the potteries, which his master, Peter Cribbs and his master's widow, managed from 1865 to 1886. The pottery, 3 miles further north on the Military road near M. P. Young's, was the place where most of the jugs, jars, etc., were made. The best of the clay for these potteries was obtained from what is now Reuben Powell's land, 2 miles west of the Military road in the northwest quarter of the norhwest quarter of S. 28, T. 14, R. 16. The pits were dug 14 feet down to the clay, which was 3 feet thick. Mr. Powell has bored with an 8 inch augur near this place, and found clay 1½ feet from the surface, 5 feet thick, dark brown and very tough and plastic. Analysis of this clay is given by Dr. Ries under No. 11 S.

Lewis J. Jones, who now lives on the Powell place in the southwest quarter of southwest quarter of Section 23, has bored a well in his yard of which the section is as follows:

Section in Well, Lamar Co.

Surface sands and loams	12	feet
Clay	1½	feet
Sand	9	feet
Clay	2	feet
White sand	24	feet
Clay, penetrated to depth of but so tough that the auger could not be raised, and the well was stopped.	2	feet

Clay is also reported at Thomas' Mills, above Hunnel's Bluff on Buttahatchie creek and on Wilson's creek near Friendship Church.

Westward from the Military road, the clay territory continues to within 10 miles of Aberdeen, where level land and white sandy soil set in.

Gattman is on the Mississippi State line, and just west of it across Buttahatchie is Greenwood Springs,4 miles from Quincy in Monroe county, Mississippi.

1232B

One and a half miles south of these Springs, there is a railroad cut 85 feet in depth, the largest cut on the road, (K. C. M. & B.) 110 miles from Birmingham. In this cut we find the following section:

Sections along K. C. M. & B. R. R., Lamar Co,

Yellow loam	5 feet
Yellow sand	15 feet
Yellow sand with streaks of clay	5 feet
Blue micaceous clay, sample No. 11, A	5 feet

Half a mile further west another section:

Yellow clay	5 feet
Ferruginous sandstone, used for ballast	10 feet
Yellow sand	20 feet
Clay with sandy layers	8 feet
Compact blue micaceous clay, sandy	12 feet

At mile post 111, the section is:

Red clay	10 feet
Banded red and white clay	10 feet
Pore, sand	10 feet

Half a mile west of the 111 mile post, the section is:

Red loam of the Lafayette formation	5 feet
Bright yellow sand	30 feet
Clay	2 feet
Light yellow sandy clay	20 feet
Red and white clay	5 feet

Near the State line, on the Kansas City, Memphis and Birmingham Railroad, 3 miles from Sulligent on the west side of Buttahatchie,a pottery has been operated. At Sulligent, Fleming W. Cribbs has lately started a pottery. He is a son of Peter Cribbs and nephew of Daniel Cribbs. His clay bed is one-half mile east of Sulligent and is 4 feet thick, and white. He says that his father carried on the business from 1838 to 1853 when he died, and his widow continued the work to 1863, his account agreeing with that of the negro, Captain, nearly as to time of operation, but placing it in entirely different decades. He has orders now for 5000 gallons (jugs) from Birmingham and Bessemer, at eight cents a gallon. He has two hogback kilns with a capacity of 800 jugs each. His clay is found in a washed out old road and is overlaid by 10 feet gravel.

Rye has a pottery, 6 miles north of Millville, Detroit P. O. Davidson Brothers have one also in same neighborhood. Lloyd has one near the Mississippi line in Itawamba county. These compete with potteries at Holly Springs, Mississippi, and Pinson's 12 miles from Jackson Tenn., for the West Tenn. and Miss. trade. From State line at Gattman to Glenn Allen, clays are very abundant and of fine quality all along the Kansas City Railroad, and this is destined to be an important center of trade in all kinds of clay manufacture. Beaver Creek flows nearly west, parallel with the railroad. Beaverton is a station on Section 17, Township 13, Range 14 west. One mile west of William Brown's place, Section 10, and on Edmund Barnes', Section 16 and on Ira Sizemore's, Section 17, clay abounds. Brown has ten feet blue clay overlaid by 10 feet cross banded yellow sand. 5 miles east of Beaverton and 2 miles west of Guin, there is 10 feet white and yellow sand and underlaid by 3 inches of ferruginous conglomerate.

FAYETTE COUNTY.

Over the greater part of the area of Fayette county, the strata of the Coal Measures are covered, to a depth increasing as we go westward, by beds of the Tuscaloosa formation capped with the red loam and pebbles of the Lafayette. Among the strata of the Tuscaloosa there are many beds of clay of purple, gray and white colors. About the Court House, a bed of white clay is reached at many points below a varying thickness of overlying strata. Thus at Mr. Sam Appling's a bed of fine white clay, 6 feet in thickness, is cut in a well, and apparently the same bed is known to underly the region about the depot. Mr. Appling's is in Section 24, Township 15, Range 13 west.

From Dr. Little's notes, I am able to give a number of details of the occurrences of these clays. Seven miles from Fayette Court House, on the road to McCollum's Bridge, is a bed of three feet thickness of very pure clay ,hard and firm, which breaks up on exposure into nodules, and the same bed shows on another road to the west of this about one mile, south of Wallace's Mill on Gilpin's creek, on W. D. Bagwell's land.

Dr. Ries' analysis of this clay is to be found in the report under number 67, S.

On the road to Pikeville, seven miles from Fayette Court House, we have the following section:

Section seven miles north of Court House, Fayette Co.

Red loam of Lafayette	2 feet
Gravel	10 feet
Clay	3 feet
Gravel	3 feet

Between the depot and the Court House Dr. Little has observed three feet of good white plastic clay in a ravine on the roadside, and the same bed is exposed in the ravines at many points on the eastern edge of the old town. Five miles west of the Court House on the Vernon road, some tan-yard vats were dug years ago, three feet into a blue clay. About half a mile from the depot, Mr. Joe Lindsay reports fine white clay, twelve feet below the surface, which, he says, was twenty feet thick.

To the westward and southwestward of the town along the line of the railroad, the clay shows in a cut one mile from the depot. On the Columbus road, four miles from Fayette, a six foot bed of clay is recorded, and five miles further west, at Hezekiah Wiggins' a bed of blue clay, four feet thick. Dr. Ries has tested and analyzed this clay under No. 32, S.

Half a mile further west, at Henry Wiggin's, there is a bored well, eighty feet deep, which, below the depth of fifteen feet, seems to be mostly in clay. One fourth of a mile beyond this, near Waldrop's, a bed of blue clay, 10 fet thick, shows at the bottom of a hill, and fifteen feet higher up another bed appears.

Along the road to Tuscaloosa at seven miles from Fayette, and also a mile further on, clay, three feet in thickness, is exposed. Again in section 13, township 17, range 12, about a quarter of a mile from Shirley's Mill, several beds of clay are shown along a hill side. One of these beds, a brown clay, about three feet in thickness, is full of finely preserved leaf impressions. and below it a fine sandy clay of three feet thickness. This is near the 11 mile post from Fayette.

Dr. Ries has analyzed two samples of the clay from this place under the numbers 68, S., and 110, and the reader is referred to these analyses and the remarks of Dr. Ries below.

Two miles southwest of Shirley's Mill on Davis' Creek, J. W. Black reports four feet of blue clay in section 25, township 17, range 12 west.

Near Doty's place, one mile east of Concord Church and about thirteen miles from Fayette, there is the following section exposed in a gully:

Section near Doty's, Fayette Co.

Red loam and sands of the Lafayette............	4 feet
Ferruginous sandstone crust........	2 inches
White clay (No. 7, Dr. Ries)..................	6 feet
Yellow sand........	5 feet
Variegated clay (No. 71, Dr. Ries)..............	2 feet
White sand..........	2 feet
Mottled clay, red and white....................	3 feet

Dr. Ries' analyses of the two clays here exposed may be seen below under numbers 70 and 71.

MARION COUNTY.

While the strata of the Coal Measures underlie the entire area of Marion county, yet these rocks do not form the surface over any great proportion of this area, since they are very generally hidden, except along the valleys of the streams, by overlying measures of the Tuscaloosa and Lafayette formations. Among the strata of the Tuscaloosa, here as in Fayette, we find many fine beds of clay. Here again, Dr. Little has collected many details of the occurrence of these clays and what follows we take mainly from his notes, though use is made also of what has been published in my Coastal Plain Report, pages 331, 332 and 333.

In the lower part of the county along the line of the K. C. M. & B Railroad, clays are exposed in railroad cuts all the way from Eldridge to Guin.

From New River crossing near Texas P. O., on to Glen Allen, several beds of clay, of no great thickness, are to be seen. A mile east of Glen Allen, in what is known as Stewart's Cut, we have the following section:

Stewart's Cut, one mile east of Glen Allen.

Gray laminated clay with fine leaf impressions...	25 feet
Ferruginous sandstone crust of irregular thickness	1 foot
Cross-bedded sands of yellow and pink colors.....	25 feet

The uppermost of the beds, above named, contains many beautifully preserved leaf impressions which are very easily gotten out. The clay has been examined by Dr. Ries under No. 18, S.

At another cut, half a mile nearer Glen Allen, we find twenty feet of white sand with two feet of white clay, and below this a blue plastic clay extending below the railroad track.

This sand has been shipped to Memphis as moulding sand for the foundry. At Glen Allen, Dr. Little gives this section:

Section at Glen Allen, Marion Co.

Brown clay	12 feet
Yellow sand	12 feet
White pipe clay	2 feet

Two miles east of Guin, on the same road, Dr. Little observes five feet of clay below a capping of red sand, and one mile west of Guin, (six miles from Beaverton) he gives the following section:

Section near Gwin, Marion Co.

Cross-bedded yellow sands	10 feet
Clay	4 feet
Sand	3 feet
Banded clay	3 feet
Sand	3 feet

On the South Fork of Buttahatchie in the vicinity of Pearce's Mill, there are several occurrences of clay and shale worth consideration. Dr. Ries collected specimens from near the mill and gives his analyses of two samples under No. 1 and No. 2, both of which he classes as refractory or fire-clays. He also gives his tests of some shales of the Carboniferous formation, which are well adapted to the manufacture of vitrified brick (No. 3). Another sample of hard and perfectly white clay was collected by Dr. Little from near the top of a hill one-fourth of a mile east of the mill. This Dr. Ries has analyzed under No. 36, S., and it is classed by him as a china clay. Dr. Little reports that, in pulverized condition, it is used as a face powder by the ladies in the vicinity.

It is, however, in Townships 9 and 10 and Ranges 11, 12 and 13, that we find the most important deposits of clay in this county. The typical locality of its occurrence is at *Chalk Bluff*, which gets its name from the white clay. Specimens collected by myself were analyzed by Dr. Wm. B. Phillips and results published in the Coastal Plain report, page 346. Dr. Little's sample was collected on the land of J. J. Mitchell, in northeast quarter of Section 8, Township 10, Range 13, from a bed five feet in thickness. The analysis of this is given below under No. 38, S., and on the same page Dr. Phillips' analysis is reprinted. This locality gives the name to the postoffice. In the same quarter section, Dr. Little has collected a sample from Briggs Frederick's land, and the analysis of this is given by Dr. Ries under No. 37, S.

Another sample from the same locality from land of Mrs. Susan Nelson, has been examined by Dr. Ries (his number 85). The same clay is reported by Dr. Little as occurring southwest of Chalk Bluff at M. E. Gassett's, Section 13. Township 13, Range 10, as well as at a number of localities within a radius of five or six miles around Chalk Bluff. This clay is hard and white, approaching pure kaolin in composition. It is in a bed, five to seven feet in thickness, and needs only facilities for transportation to become one of the most valuable deposits in the State.

Between Pikeville and Hamilton, clays are of frequent occurrence, one of these near the former place and some ten miles from Hamilton, collected by Dr. Little has been analyzed by Dr. Ries, (No. 65, S.)

Westward from Hamilton to the Mississippi line and beyond, Dr. Little reports many occurrences of clay of various qualities. From the vicinity of Bexar, three samples of clay have been collected by

Dr. Little and analyzed by Dr. Ries, (numbers 12, 40 S. and 41 S.). The bed in this region is about four feet in thickness. Nos. 12 and 40 are from H. Palmer's and No. 41 from Bexar, a mile further west, near Pearce's Store and Mill.

Near the State line on the road to Tremont, Miss., twenty feet thickness of clay is reported as being cut in a well.

Beyond the State line, the clays continue, and at Davidson's Store, Lloyd's pottery, they are put to a rather remarkable use, namely for head stones of graves, for which purpose they are moulded into flat tablets, provided with suitable inscriptions and then baked. These stones appear to be quite durable although necessarily liable to be broken.

A number f potteries in this vicinity use this clay which is about four feet in thickness, and quite similar to that mentioned above as occurring about Gattman in Lamar county, on the K. C. M. & B. Railroad.

The Bexar variety of clay extends for a good many miles northward up Hurricane Fork and along Bull Mountain Creek.

FRANKLIN COUNTY.

In Franklin county the underlying Paleozoic rocks of Carboniferous and Subcarboniferous ages are exposed along the valleys of the streams, but everywhere else are covered with a mantle of varying thickness of the sands, clays and pebbles of the Tuscaloosa and Lafayette formations.

As in the other counties adjoining towards the south, so in this, it is in the Tuscaloosa strata that we find the important deposits of clay. In parts of the county, especially in the vicinity of Russellville, valnable deposits of limonite or brown iron ore have been for many years and are now being worked to supply the furnaces at Sheffield and Florence.

Associated with these ore beds are *clay horses*, as they are called, which, in places, yield an abundance of fine white clay.*

Other occurrences of the clays of the Tuscaloosa formation, not associated with the iron ores, have been recorded by Dr. Little, from whose notes the following details have been obtained.

On the southern boundary of the county, near Savoy postoffice, in T. 8, R. 14, near Dr. Kilgore's Mill, a bed of blue plastic clay three feet thick is noted, above which, one hundred feet up the hill, is a bed of four feet thickness of red clay or ochre (red chalk), and just above this a bed four feet thick of pure, hard, white clay, like that of Chalk Bluff, in Marion county. The same beds are to be seen at many points around Savoy within a radius of three miles. Half a mile west of Burleson a bed three feet in thickness of white clay is found immediately overlying the blue limestone of the Subcarboniferous formation. Along the road from Burleson to Belgreen the clay is exposed at several points.

Northwest of Russellville, on the road to Frankfort, large deposits of white clay were reported, but not seen by Dr. Little.

Near the State line, in S. 9, T. 7, R. 15, on Gilley's branch, occurs a bed of clay from which material has been obtained for a pottery formerly worked by Mr. Chaney, two miles east of Pleasant Ridge, Miss.

Southward of this locality, in S. 20 and S. 29, of T. 8, R. 15, Mr. Thomas Rollins has a bed of clay four

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*Valley Regions Report, Part I, pages 211 and 215.

feet in thickness, a sample from which has been tested by Dr. Ries, No. 62 S. The country for several miles in all directions about Rollins' is rough and hilly, the hills capped with beds of pebbles and a ferruginous sandstone crust, but the beds of clay, interstratified with sands, seem to make up a very considerable proportion of their bulk.

COLBERT COUNTY.

In the northern and eastern parts of this county the strata of the Subcarboniferous formation make the surface, but in the southern and western parts these older formations are covered by the mantle of sands, pebbles and clays of Tuscaloosa and Lafayette formations, the former of which carries the important clay deposits here as elsewhere. The best of these clays occur near the western border of the county, as well as in the adjacent parts of Mississippi.

The station Pegram, on the Memphis and Charleston Railroad, seems to be about the central point in this clay region. Some extensive works for the manufacture of fire brick and other kinds of brick have been established here under the name of the "Alabama Fire Brick Works." The clay is obtained from the southwest part of S. 27, the northeastern part of S. 3, and the northwestern part of S. 34, in T. 3, R. 15 W. The clay appears in several beds, as shown by the section below, which is taken from the notes of Dr. Little.

Section near Pegram, Colbert Co.

Pebbles of large size with sands.................	30 feet
White clay, one-eighth of a mile from mill.......	3 feet
Small gravel..........	1 foot
White clay, sample No. 55, S..................	6 feet
Sand with large gravel overlying..............	16 feet
Yellow clay, sample No. 56, S..................	6 feet
White clay........	1 foot
Purple and black clay, sample No. 57, S..........	10 feet
Gray clay, sample No. 58....	5 feet

On land belonging to Mrs. C. Rhea, in the vicinity, Dr. Little gives the section as follows:

Yellow loam	1 foot
Sandy clay (fire clay), sample No. 59	5 feet

Of these clays Dr. Ries has analyzed and tested Nos. 55, 56 and 57; No. 56 being classed by him among the china clays, while the other two are ranked as fire clays. The brick from this locality are used in Sheffield for lining the furnaces, and they are also used by the railroad.

In the Valley Regions Report, Part I, are given three analyses of clays collected from this region near the State line. These are as below:

Analyses of Clays from near Pegram.

	1.	2.	3.
Combined water	8.250	6.827	7.085
Silica	66.122	76.911	68.108
Alumina	24.781	11.173	10.858
Ferric oxide	trace	3.449	14.471
Total	99.153	99.360	100.522

(1.) A light colored clay with small lumps of gritty matter.
(2.) A dark gray clay with black specks of organic matter.
(3.) A pinkish clay with white specks.

The light colored clay (1) above has been seen also on the south side of Little Mountain, near the bottom of the pebble hills, along the county line, a few miles northeast of Frankfort. It shows here in an irregularly stratified seam beneath the pebble bed. It is quite pure and white, and has occasionally found use as a whitewash, for which purpose it seems well adapted.*

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*Valley Regions, Part I, page 180.

LAUDERDALE COUNTY.

The Tuscaloosa formation, which carries the clay deposits, covers only the western half of Lauderdale, the Subcarboniferous rocks forming the surface over the eastern half. The clays are white, red and mottled, and generally quite plastic. Mr. McCalley gives some notes concerning them.

At the Tan-Yard Spring, in the N. E. ¼ of the N. W. ¼ of S. 24, T. 1, R. 14 W., there is the following section:

Section at Tan Yard Spring, Lauderdale Co.

Ferruginous crusts........	1 foot
Clay, somewhat stained with iron, unctious and plastic when wet.........	5 feet

This clay has been analyzed by Dr. Pickel, of the University of Alabama, with the following results:

Analysis of Clay, Tan Yard Spring, Lauderdale Co.

Silica......	59.65
Aumina....	27.04
Ferric oxide..........	4.75

In the gullies, near the top of the divide between Brush and Bluff creeks, in the southwest of the northeast of S. 30, T. 1, R. 13 W., there are deposits of white unctuous clay from seven to eight feet thick.*

Dr. Little's notes supply some additional information about the clays of this county. Mr. Wm. J. Beckwith has a clay deposit four and one-half miles from Wright's postoffice, on Brush Creek. It is upon a high hill, and is five or six feet in thickness. The clay is of a light yellow color, and is firm, fine grained and smooth. It has been shipped north and

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*Valley Regions, Part I, page 105.

sold for $12 a barrel, and can be delivered, barreled, on the boat on the Tennessee river for $1 a barrel.

There is a red clay, suitable for paint, belonging to the Sheffield Paint Company, near the county line, six miles from Iuka, Miss. The bed is ten feet thick. The white clay from Clingscale's Mill, Miss., mentioned above in the extract from Dr. Hilgard's report, comes from localities near the State line, west of Lauderdale county.

In many parts of this county there are beds of white pulverulent silica, which have occcasionally found use. Thus at Florence the Mineral Paint and Tripoli Company make a paint by mixing clay and this fine silica together. At Waterloo, also, the same white silica appears, as at Eastport, in Colbert county. This material has been used in the manufacture of glass at Pittsburg, Pa.

TERTIARY AND POST TERTIARY FORMATIONS.

The clays from these two formations have not yet been specially investigated, the only representative herein contained being the flint clay from Choctaw county. The material is spoken of under the head of Fire Clays. There is a very great abundance of this clay in the counties of Choctaw, Clarke, Conecuh, etc., in the lower Claiborne or Buhrstone division of the Tertiary. Over the greater part of the Coastal Plain, in the river second bottom or Post Tertiary formations, there is the best of the yellow loams which are suitable for the making of the ordinary building brick. These loams correspond in age, approximately, to the Plisocene clays of the northern states, which are so extensively used for the same purposes. Besides these second bottom deposits, there are lens of pure plastic clays to be found in many places interstratified with the prevailing sands of the formation. Many of these clays have been received and superficially tested, but it is the intention to extend the present investigation over that part of the state in the near future.

PRELIMINARY REPORT OF THE PHYSICAL AND CHEMICAL PROPERTIES OF THE CLAYS OF ALABAMA,

BY HEINRICH RIES, PH. D.

The tests which are described below were made in part on samples collected by the writer, and in part on samples collected by Prof. Smith. In the examination of the different lots of clay an endeavor has been made to perform such tests on the materials as would tend to give information of value to the practical clay worker.

This therefore includes the determination of the shrinkage of the clay in drying and burning, the degree of its plasticity, the color when burned at different temperatures, the temperature of incipient fusion, vitrification, and viscosity, and other minor points.

In some cases it is possible to state what the possible applications of a given clay are, but in many instances any one clay is susceptible of being mixed with two or three other clays and utilized in four or five different ways. The main point therefore, is to point out the properties of the deposits, so that the manufacturer may find out more readily whether the State contains materials of the nature desired by him, and in what portion of the State they are to be found.

It may be said in general that the results of the tests made indicate the occurrence of a great diversity of clays in the State, ranging from the more impure and easily fusible ones to the very refractory bauxites, which are unaffected by high temperatures.

These investigations relate chiefly to those deposits which have not yet been worked, with a view to aid the development of Alabama's clay resources; and consequently little is said with regard to the industry already established.

Where a number in parenthesis follows the name of the locality, it refers to the number in the writer's note book, unless succeeded by the letter S in which case the number is that on the label furnished by Dr. Smith.

The clays examined by me have been classified below as follows: China Clays; Fire Clays; Potters' Clays; Brick Clays; Miscellaneous Clays, and a few pages have been added on the utilization of clays, in the manufacture of Portland Cement.

CHINA CLAYS.

China clays might include those used in the manufacture of porcelain and white earthenware, and of these, two grades are recognized, i. e., kaolins, or china clay proper, and ball clays. The former possess little plasticity, a low percentage of fusible impurities, are generally highly refractory and burn to a pure white body. Very few kaolins can be put on the market in the condition in which they are mined, and most of them have to be washed in order to eliminate impurities which would tend either to discolor the clay or to render the texture far too coarse. The tensile strength of kaolins may vary from 5 to 15 lbs. or even reach 25 lbs., and the influence of this low strength is overcome by the addition of plastic ball clay. Iron is a very objectional impurity and should not exceed 1 per cent. indeed the less of it the better. Alkalies, if present as silicates, are not wholly undesirable for they serve as beneficial fluxes, but if contained in the clay as sulphates they may cause blisters, especially if the clay is heated too rapidly, and the same holds true of sulphate of lime or gypsum. Many washed kaolins approach very closely to the theoretical composition of kaolinite, while others even when washed may contain a high percentage of total silica due to the presence of much quartz and perhaps feldspar. If these two accessory minerals contain no iron they are harmless, especially if finely divided, and the rational analysis of clay is known. (See method of clay analysis.) The term kaolin is usually, and always should be restricted to white burning clays of residual origin. They are in most instances highly refractory, but they might also be of such composition as to bring about fusion at a low temperature, and at the same time burn white. It is the absence of plasticity in kaolins that necessitates the addition of ball clay, but some manufacturers use only the ball clay, mixed with quartz and feldspar for making porcelain. The last two minerals are indispensable ingredients of white-ware mixture, quartz being added for the purpose of preventing excessive shrinkage, and feldspar on account of its easy fusibility binding the mass together.

China clays should contain a low percentage of iron oxide, in fact the less the better, for in burning this compound tends to color the clay yellow or red. While the percentage of iron oxide should be under 1 per cent., nevertheless many of the best china clays used contain 1.25 to 1.35 per cent. of iron oxide. This production of a yellowish tint from such a quantity is prevented in two ways, first by adding a small amount of cobalt oxide to the white-ware mixture, or secondly by taking advantage of the fact that when the kiln, in which the ware is burned, is heated to a high temperature the fire tends to act reducing, thereby changing the iron coloration from yellow to bluish or bluish gray, and making it less noticeable.

Ball clays are used to mix with kaolin in the manufacture of porcelain and white-ware in order to give plasticity to the mass. They should be as free from fluxing impurities and mineral fragments as possible, and sometimes have to be washed. They generally burn nearly as white as kaolin. Ball clays should have a good tensile strength, not less than 60 lbs. to the square inch. They are often dark brown or even black from the presence of abundant organic matter, but this color disappears on heating. This organic matter exerts no other effect on the clay than to increase the plasticity and air-shrinkage.

The Alabama clays included under this heading are those which burn white or very nearly so at a moderately high temperature. Many of the specimens examined are quite siliceous, and consequently exhibit a low shrinkage in burning, while nearly all of them are of sedimentary origin. a few, such as those associated with the bauxite deposits, having an origin in common with them.

In respect to their geological relations the china clays here reported on come from three horizons, (1) the Cambrian and Silurian limestone, e. g. No. A. S. from Rock Run; No. 190 from near Gadsden; and No. 205 from near Kymulga, in Talladega Co. (2) the lower Sub-carboniferous cherty limestone; e. g. Nos. B. S; 128, and 214, from Willis' Valley, between Fort Payne and the Georgia state line. (3) the lower Cretaceous or Tuscaloosa formation, e. g. No. 38. S; No. 85; No. 37. S from Chalk Bluff and vicinity, Marion county: No. 37. S from Pearce's Mill, Marion county. and No. 56. S from Pegram in Colbert county.

Of the above, only the clays from Will's Valley have been regularly mined.

CHINA CLAY.

FROM DYKE'S ORE BANK, ROCK RUN, CHEROKEE CO.
(NO. A. S.)

A white, soft, gritty clay, which slakes easily in water.

The clay requires the addition of 30 per cent. of water to make a workable mass, which is quite lean. Bricklets made from this shrunk 4 per cent. in drying and an additional 12 per cent. in burning, making a total shrinkage of 16 per cent.

The tensile strength of the air dried briquettes is low, being only 9 lbs. per square inch on the average, with a maximum of 12 lbs. per square inch.

Incipient fusion occurs at 2000 degrees, F. The clay burns to a hard, marble like, dense body with a very faint bluish tinge at 2100 degrees F.

The analysis of the clay is as given below.

Analysis of China Clay, Rock Run, Cherokee Co. (No. A. S.)

Silica	60.50
Alumina	26.55
Water	7.20
Ferric oxide	.30
Lime	.90
Magnesia	.65
Alkalies	2.70
Moisture.	.70
	99.50
Total fluxes	4.55
Specific gravity	2.52

The rational composition is

Clay substance	70.30
Quartz	18.00
Feldspar	12.20
	100.50

CHINA CLAY.

TWO MILES N. OF KYMULGA, TALLADEGA CO. (NO. 205.)

A hard white clay, plainly stratified, due to the abundance of many white mica scales arranged parallel with the bedding. It is fine grained with a small amount of fine grit. It slakes very slowly breaking into scaly fragments.

When ground to pass through a 100 mesh sieve it required 18 per cent. of water to mix it up, and give it a mass which was only moderately plastic, owing to the high amount of mica which it contains.

The air shrinkage of the clay when thus mixed is 5 per cent.

When burned to about 2200° F, the color was pure white, and the total shrinkage 8½ per cent., but incipient fusion had not been reached.

At 2350° F, the color was white, and the total shrinkage 11 per cent.

In both cases the bricklets showed a tendency to crack in burning.

Incipient fusion occurred at cone 27 in the Deville furnace, but at cone 30 vitrification was not complete.

If used by itself it would probably not be safe to use the clay in its raw condition above 2250° without developing a yellowish tinge, although this migh not be noticeable when ball clay and quartz and feldspar were mixed.

The mica interfers with the tensile strength just as it did with the plasticity, so that the former did not exceed 15 lbs. to the square inch and varied between that and 12 lbs. per square inch.

The chemical analysis of the material is as follows:

Analysis of China Clay near Kymulga, Talladega Co. (No. 205.)

Silica	50.45
Alumina	35.20
Ferric oxide	.80
Lime	.60
Magnesia	.62
Alkalies	——
Ignition	12.40
	100.07
Total fluxes	2.02

The clay would no doubt work for the manufacture of white tile; or white earthenware, but could not be used for porcelain without being washed.

(No. B. S.)

CHINA CLAY,

EUREKA MINE, DEKALB CO.

It is whitish clay, with little or no grit, and of remarkable purity. In water it breaks up slowly to small grains.

It took 33 per cent. of water to temper it, and gave a lean mass, which shrunk 2 per cent. in drying, and an additional 6 per cent. in burning, giving a total shrinkage of 8 per cent. Air dried briquettes of the clay had an average tensile strength of 25 pounds per square inch, with a maximum of 27 pounds.

Incipient fusion occurs at 2300° F. vitrification at 2500° F., and viscosity above 2700° F.

The clay burns to a very white, smooth body.

An analysis of the clay gave the following results:

Analysis of China Clay, Eureka Mines, DeKalb Co. (No. B S.)

Silica	47.00
Alumina	38.75
Water	12.94
Clay base	98.69
Ferric oxide	.95
Lime	.70
Magnesia	tr
Alkalies	tr
	100.38
Total fluxes	1.65
Specific gravity	2.34

This clay approaches closely to kaolinite in its composition.

(No. 128.)

CHINA CLAY,

H. H. GRIFFIN, EUREKA MINE.

This is a white clay, which represents the best quality obtained in the mines of H. H. Griffin, four miles northeast of Valley Head.

It is a very gritty, lean clay, which took 38.50 per cent. of water to work it up.

The air shrinkage was 3½ per cent., and at 2250° F. it had only shrunk 6 per cent., and barely showed signs of incipient fusion. Vitrification takes place at 2800° F. The analysis of a clay from this locality, from what is known as the Eureka Mine, and made by A. T. Brainard, was kindly furnished to the writer by Mr. Griffin. It is as follows:

Analysis of China Clay, Eureka Mines, DeKalb Co.

Silica	53.7300
Alumina	34.5390
Ferrous oxide	.8530
Lime	.4144
Magnesia	.3420
Alkalies	tr
Sulphuric acid	.2018
Phosphoric acid	.0522
Ignition	12.28
	102.4124
Total fluxes	1.609

The following analysis of sample collected by writer from the mines in 1897, gave the following:

Analysis of China Clay, Eureka Mines, DeKalb Co. (No. 128.)

Silica	82.11
Alumina	11.41
Ferric oxide	1.40
Lime	tr
Magnesia	.661
Alkalies	1.80
Ignition	4.001
	4.001
	101.382
Total fluxes	3.86

The rational analysis gave.

Clay substance	20.20
Quartz	69.20
Feldspar	10.40
	99.80

The feldspar percentage influences the fusibility of this clay, and the difference in the two quantitative analyses is due to the latter having been made on an unwashed sample.

(No. 214.)

CHINA CLAY,

FROM F. Y. ANDERSON, NEAR FORT PAYNE, DEKALB CO.

This clay is rather sandy in its nature, unless ground extremely fine, the granular character being due partly to the halloysite which it contains.

It slakes very slowly and incompletely, and took in its air dried condition 30 per cent. of water to work it up.

The air shrinkage of the bricklets was 7 per cent. At cone 27 in the Deville furance, it was white and showed traces of incipient fusion. At about 2350° F., it burned white without a trace of yellowish color, and with a total shrinkage of 11 per cent.

It is evident that this material could be used in the manufacture of white ware. It would, however, take much grinding to develop its plasticity fully.

The tensile strength was from 60 to 65 pounds per square inch when the material was ground to 60 mesh, and the briquettes are very constant in strength. With finer grinding the tensile strength would very probably increase.

The chemical analysis yielded:

Analysis of China Clay, F. Y. Anderson, DeKalb Co. (*No.* 214.)

Silica	53.50
Alumina	34.45
Ferric oxide	.21
Lime	.30
Magnesia	trace
Alkalies	.21
Ignition	13.20
	101.87
Total fluxes	.72

(No. 38 S.)

CHINA CLAY.

J. J. MITCHELLS, CHALK BLUFF, MARION CO.

Pure white, fine grained clay, brittle when dry, and with conchoidal fracture. It slakes easily in water, all of it passing through a 60 mesh sieve and most of it through a 100 mesh one.

The clay ground to pass through a 30 mesh sieve, and mixed with 24 per cent. of water, gave a lean mass whose air shrinkage was 4 per cent. and an additional shrinkage of 3 per cent. took place in burning, giving a total of 7 per cent.

Air dried briquettes of the clay gave the usual low tensile strength of kaolin, the average being 15 pounds per square inch, with a maximum of 17 pounds per square inch.

Incipient fusion occurs at 2300° F., vitrification at 2600° F., annd viscosity at 2700° F.

The clay burns to a clear white body. Its composition is as follows: (No. 1 being by H. Ries and No. 2 by W. B. Phillips. No. 3 is the composition of pure kaolin given for comparison.)

Analyses of China Clay, Chalk Bluff, Marion Co.

	1	2	3
Silica	47.25	47.20	46.30
Alumina	36.50	37.76	39.80
Water	13.35	14.24	13.90
Ferric oxide	2.56	tr	
Lime	tr	tr	
Magnesia	tr	tr	
Moisture	.50	tr	
	100.16	99.20	100.00

Total fluxes (!) 2.56
Specific gravity 2.44

(No. 85.)

CHINA CLAY.

CHALK BLUFF, MARION CO.

This clay which occurs on the property of Mrs. Nelson is a smooth, white, fine grained clay with a conchoidal fracture. It slakes easily into angular grains. It is very lean, and requires 33 per cent. of water to mix it up. The tensile strength is also very low, being only 15 pounds per square inch. The air shrinkage is 4 er cent.

At 2200° Fahr. the total shrinkage was 10 per cent. At. 2350°, it was 15 per cent., and the bricklet incipiently fused, with a yellowish white color.

At 2500°, the total shrinkage was 18 per cent. The color was yellow. Vitrificaton occurred at 2700° F.

In the Deville furnace, at cone 27, the clay was nearly viscous.

No analysis was made of this clay.

(No. 37 S.)

CHINA CLAY.

BRIGGS FREDERICK, NEAR CHALK BLUFF, MARION CO.

This was a fine grained clay, 90 per cent. of it passing through a 60 mesh sieve. The clay took 25 per cent. of water to be worked up, and even then was lean and granular, fine grinding being necessary to develop proper plasticity.

The air shrinkage was 2½ per cent. and the fire shrinkage was the same, giving a total shrinkage of 5 per cent. in the case of a sample ground to pass through a 30 mesh sieve.

The air dried briquettes showed an average tensile strength of 14 pounds per square inch, and a maximum of 16 pounds.

Incipient fusion occurs at 2300° F., vitrification at 2500° F., and viscosity above 2700° F. The clay burns to a white but somewhat porous body.

Its composition is as follows:

Analysis of China Clay, Briggs Frederick, Marion Co. (*No.* 37, S.)

Silica	65.49
Alumina	24.84
Water	7.50
Ferric oxide	tr.
Lime	1.26
Magnesia	tr.
Alkalies	tr.
Moisture	.30
	99.37
Total fluxes	1.26
Specific gravity	1.76

This clay is very low in iron, and the small percentage of lime is no detriment.

(No. 36 S.)

CHINA CLAY.

PEARCE'S MILL, MARION CO.

A hard, porous, coarse grained, gritty clay, which in water breaks up slowly into angular fragments, each of which in turn keeps splitting.

Twenty-five per cent. of water was required to work it up, but it is very lean. The air shrinkage was 3 per cent. and an additional 12 per cent. in burning, making a total of 15 per cent.

The tensile strength of air dried briquettes varied on the average 12-14 pounds per square inch with a maximum of 20 pounds per square inch.

Incipient fusion occurred at 2300° F., vitrification at 2500° F., and viscosity at over 2700° F.

The clay burns at 2300° F. to a very white body.

The analysis of it yielded.

Analysis of China Clay, Pearce's Mill, Marion Co. (*No.* 36, S.)

Silica (combined)	38.60	
Alumina	32.50	
Water	11.05	
Clay base		82.15
Silica (free)	17.68	
Ferric oxide	.20	
Lime	tr.	
Magnesia	tr.	
Alkalies	tr.	
Moisture	.20	
	100.03	
Total fluxes	.20	
Specific gravity	2.33	

With washing, this clay would probably be well adapted to the manufacture of the highest grades of pottery. It contains less fusible impurities than most of the kaolins used in this country, and the probabilities are that if the deposit were constant in its character it might not require washing.

(No. 56 S.)

CHINA CLAY.

PEGRAM, COLBERT CO.

A fine grained, whitish, homogeneous but not very dense clay with a smooth fracture.

In water it slakes slowly to grains under a sixtieth of an inch (1-60 in.)

Thirty per cent. of water was required to make a workable mass, which to the feel was quite lean. The air shrinkage of bricklets made from it was 7 per cent., and 4 per cent. in burning, making a total of 11 per cent.

The tensile serength of the air dried briquette was quite low, being 40 pounds per square inch on the average, with a maximum of 53 pounds per square inch.

Incipient fusion occurs at 2200° F., vitrification at 2400° F., and viscosity at 2600° F.

The clay burns to a white body which is hard and dense, the following is the analysis of the clay.

Analysis of China Clay, Pegram, Colbert Co. (No. 56, S.)

Total Silica	64.90
Alumina	25.25
Water	8.00
Moisture	.90
Ferric oxide	trace
Lime	trace
Magnesia	trace
	99.05
Free silica	34.40
Specific gravity	2.35

The material is to be looked upon as a white-ware clay of good grade, from which the sand could be removed by washing if necessary. There are practically no published analysis with which this agrees very closely, but a comparion is not necessary as the purity of the material is self evident.

FIRE CLAYS

The term fire-clay is applied to those clays which will resist a high temperature without fusing.

Fire clays are of two kinds, flint clays and plastic clays.

The flint clays generally approach kaolinite in composition, but have no plasticity, or at the most a very slight degree of it. They are generally of a highly refractory nature, their fusing point being commonly above 2700° F. and their shrinkage in drying and burning is extremely low. They therefore make an excellent grog to add to the more plastic clays for the purpose of reducing their shrinkage. Flint clays have thus far not been found in Alabama, except in Conecuh, Choctaw, Washington, Clarke and Monroe counties.

Plastic fire clays are widely distributed and are especially abundant in the Coal Measures of many states, but they may also ocsur in the Cretaceous and Tertiary formations. Those of the Carboniferous are often of a shaly nature and to be ground before their plasticity can be brought forth.

The requisite qualities of a fire clay vary somewhat according to the use to which it is to be put, and it is still a disputed point, just what temperature the fusion point of a clay should exceed in order to be classed as a refractory one. As it now stands, many American clays are unfortunately and erroneously classed as fire clays which can not withstand a temperature of more than 2300° or 2400° F. Many of the New Jersey fire clays require a temperature of from 2500° to 2600° F. to burn them.* The fire clays of Missouri fuse at from 2400° to above 2700°.

No arbitrary line can be drawn between refractory and semi-refractory clays, but if such a division were made it would seem advisable not to call any clay refractory which is affected by a temperature of less than 2700° F. Many of the Alabama fire clays conform to this definition.

While it is desirable that fire clays should posses good plasticity and low shrinkage, the main point is their refractoriness. It may be said in general that the fusible impurities of a fire clay should not exceed 3½ or 4 per cent., but these limits may be extended somewhat in either direction depending upon the nature of the flux and whether the clay is fine or coarse grained.

The shrinkage of a fire clay in burning may often be counteracted by the addition of grog, i. e. sand, ground fire brick, or similar substances.Fire clays which are too fat and plastic are likely to crack in burning, but at the same time they give a dense body. It is desirable that any burned clay or grog which is mixed with the raw material should have previously been burned as dense as possible. Fine grains of powdered grog permits the brick to shrink more in burning than the course and bricks with the latter generally stand changes of temperature better. Next to burned clay, quartz is perhaps the most important grog, and flint clay serves a similar purpose.

If a fire brick made only of clay and clay grogs still shrinks when placed in the furnace, sharp quartz grains should be added, as they have a tendency to expand on repeated heating. Fine grained quartz sand should in no case be added if the brick is to be exposed to high temperatures, for in such cases it tends to flux the clay in burning, furthermore the addition of coarse quartz must also be within limits for if in too large quantity the quartz grains loosen the brick by their expansion. A good fire brick is sometimes made by mixing a non-plastic refractory clay with a very plastic dense burning, semi-refractory one.

No fixed rules can be laid down to govern the selection and valuation of a fire clay for the reason that the use to which it is to be put determines its qualities to a large extent. All fire clays should resist a high temperature. Some are used in situations requiring resistance to heat and these must be coarse grained. Others when burned into bricks must resist corrosion and consequently should burn to a dense product, as in the case of glass pot clays.

Fire bricks.—These should show a resistance to high temperatures, and also the fluxing action of ashes from the fuel, which contain carbonates, sulphates, and phosphates of the alkalies and alkaline earths. In addition they should withstand the corrosive action of fused metallic slags, alkalies, and glasses.

The density of the fire brick is often of great importance especially where it is to resist the corrosive action of molten material. The fat plastic clays are those which usually burn to the most dense body, but in doing so they frequently crack to such an extent that grog has to be added to them.

Porous, coarse grained bricks on the other hand stand heat better.

The fire-clays below reported on come from four geological horizons, viz., (1) The Cambrian and Silurian limestone formations of the Coosa Valley region; No. 191 from Peaceburg, Calhoun county; No. 127 Stevens, from Oxanna, Calhoun Co.; the refractory clays of Rock Run, Cherokee Co.; and the bauxites from the same locality. (2) The cherty limestones of the lower Subcarboniferous formation of Wills' Valley; No. 117 and 116 from the Montague mines, and No. 119 from near Valley Head in DeKalb county. (3) The Tuscaloosa formation of the lower Cretaceous, No. 112 from Bibbville, and No. 111 from Woodstock in Bibb county; No. B from near Hull's Station, and No. 118 from near Tuscaloosa in Tuscaloosa county; Nos. 1 and 2 from Pearce's Mills in Marion county and No. 57 S. from Pegram in Colbert county. (4) The lower Tertiary formation, No. C S from Choctaw county. Of these only the clays from Bibbville and Woodstock have been regularly mined.

(No. 191.)

FIRE CLAY.

FROM PEACEBURG, NEAR ANNISTON.

A grayish white clay of very fine grain, and containing a noticeable amount of very fine mica scales. In water it slakes moderately fast.

Twenty-five per cent. of water was required to work it up, and the resulting mass was rather lean, and had a somewhat flaky structure, which interferred with the development of the plasticity.

Bricklets made from the mixture had air shrinkage of 5 per cent.

When burned to about 2100° F. the total shrinkage amounted to 10 per cent, the clay was white with a faint tinge of yellow and the brick was still very porous. At about 2250° F. incipient fusion has barely been reached, with a total shrinkage of 13 per cent., the color being white tinged to a noticeable extent with yellow. At about 2300° F. the bricklet burned cream color, was incipiently fused, and the total shrinkage amounted to 15 per cent.

In the Deville furnace the clay vitrified at cone 30, but did not lose its shape.

Owing to the leanness the tensile strength was very low, and ranged from 20 to 25 pounds per square inch.

The chemical analysis of the clay gave:

Analysis of fire clay, Peaceburg. Calhoun Co. (No. 191.)

Silica	51.90
Alumina	35.00
Ferric oxide	.99
Lime	.23
Magnesia	.10
Alkalies	.55
Ignition	11.30
	99.87
Total fluxes	1.87

The low plasticity of this clay would probably interfere with its being used alone, but owing to its refractory nature and the light color developed in burning it could no doubt find use as an ingredient of other clay mixtures.

(No. 127 of Mr. Stevens.)

FIRE CLAY.

FROM OXANNA, CALHOUN COUNTY.

This is a coarse and sandy clay, which mixes up to a lean mass with only 16 per cent. of water. The tensile strength is very low, being on the average of 9 to 10 pounds per square inch, and the air shrinkage is 2 per cent.

The following is the behavior of the clay at successively higher temperatures.

At 2200° F. the color was grey white.

At 2250° F. shrinkage 3 per cent., color buff.

At 2300° F. shrinkage and color same.

At 2400° F. shrinkage 3 per cent., color buff, showing specks of ferric oxide.

At 2500° F. the shrinkage was only 2 per cent., having undergone a slight swelling owing to the very high quartz percentage. Incipient fusion had not occurred up to this point. The following is the analysis of this clay.

Analysis of Fire Clay, Oxanna, Calhoun Co. (*No.* 127, *Stevens*).

Silica	84.21
Alumina	9.75
Ferric oxide	.69
Lime	.70
Magnesia	.14
Ignition	4.10
	99.59
Total fluxes	1.53

REFRACTORY CLAYS

OF ROCK RUN, CHEROKEE COUNTY.

Associated with the bauxites at Rock Run are a number of clays, most of them of fine grained texture, but some showing small quantities of grit, and which vary in color from pure white to mottled ones, which at times contain an appreciable percentage of sand. Samples of these clays from six different locations have been tested, they come from what are known as the Dykes old Iron Ore Mine and the Dykes Bauxite Mine, on the property of the Rock Run Iron Mining Co. in Cherokee county.

No. 1. is on the north side of the iron mine reservation at the extreme western end; No. 2 and 3 are from the same side of the pit, but at points 125 and 200 feet farther east respectively; No. 4 is from the western end of the Bauxite pit and on the north side of the entrance to it; No. 5 is on the north side of the same pit and No. 6 at the eastern end of it.

Nos. 1, 2, 3, each show a face 15 to 20 feet in height, and are of probably greater thickness. No. 4 is looked upon as a very low grade of bauxite.

The following tests mere made upon these samples:

No. 1. This is a fine grained white clay, with a splintery fracture, showing iron stains along the joint cracks and other planes or fracture, but none in the interior of the mass. It slakes quickly but not completely into angular fragments. In mixing it up, 32 per cent. of water was required and the resulting mass was lean and granular. It had been previously passed through a 30 mesh sieve, and it ground to a finer mesh would, no doubt, be more plastic. The lean granular character gives it a very low tensile strength amounting to not over 6 pounds.

The air shrinkage of the clay was 4 per cent. at about 2200½ F., the total shrinkage was 9 per cent; and at about 2300°, 18 pr cent., at about 2500°, the total shrinkage was 21.50 per cent, and the color of the burned bricklet was still white.

When tested in the Deville furnace at cone 30 the form of the clay still remained sharp, and it was white in color, but showed signs of incipient fusion.

The composition of the clay is as follows:

Analysis of Fire Clay, Rock Run, Cherokee Co. (No. 1.)

Silica	47.60
Alumina	36.70
Ferric oxide	1.10
Lime	1.30
Magnesia	trace
Alkalies	trace
Ignition	14.20
	100.90
Total fluxes	2.40

These tests indicate that the clay is quite refractory, and its burning to a white color would permit its being used for products having a white body. The high shrinkage is somewhat against it, but this could be counteracted to a large extent by the addition of quartz and it would also be necessary to mix it with some plastic clay, if it was to be molded when wet.

No. 2. This is similar to No. 1 in its color and texture. It is however much more plastic than the other although it only required 31.25 per cent. of water to mix it, the tensile strength however is very low, and in this case bears no relation to the plasticity, the air shrinkage of the clay is 3 per cent; at about 2200° F., the total shrinkage was 10 per cent. and the bricklet was still absorbent although incipient fusion had just begun, while the color was yellowish white; at about 2250° F., the total shrinkage was 14 per cent., the bricklets had an absorption of about 5.7 per cent. and the color still a yellowish white. At about 2300° F. the total shrinkage was 16 per cent., the absorption only 2 per cent. while its color was a very faint yellowish gray; the total shrinkage was 17 per cent. at 2400° F., and the bricklet which appeared nearly vitrified, was gray in color.

In the Deville furnace at cone 30, the form of the clay was still perfectly sharp, and while it was thoroughly vitrified it showed no evidence of becoming viscous.

The rational composition of the clay was:

Clay substance	94.54
Quarts	5.80
Ferric oxide	.26

No. 3. This is likewise a white clay but one containing much fine grit, not very porous, and slaking quickly to a powder. It is also a very plastic clay, and took 36.50 per cent. of water to work up, but the tensile strength again is very low, being not over 5 pounds. The air shrinkage was 3 per cent.; at about

2200° F., the total shrinkage was 12 per cent., and the bricklet white, with an absorption of 7.20 per cent. At about 2250° F. the total shrinkage was 13 per cent. and the bricklet, which had an absorption of 6.3 per cent. was white with a very faint tinge of yellow. At about 2300° F., the total shrinkage amounts to 15.5 per cent., the color of the bricklet white with a mere shade of gray, and the absorption of it had decreased to 1.3 per cent. The total shrinkage at about 2500° F. was 17.5 per cent. and vitrification had occurred, the bricklet being whitish in color.

In the Deville furnace at cone 30, the form of the clay pyramid was still erect, and while the clay was thoroughly vitrified the angles were still sharp and color whitish. The composition is:

Analysis of Fire Clay, Rock Run, Cherokee Co. (No. 3).

Silica	72.20
Alumina	22.04
Ferric oxide	.16
Lime	.50
Magnesia	.40
Alkalies	.60
Ignition	5.80
	101.70
Sand	34.52
Total fluxes	1.66

No. 4. This clay as has already been stated is a low grade bauxite, it is white in color with a slight yellowish tinge and portions of it show a pisolitic structure. It slakes quickly. 31.35 per cent. of water were required to work it up and even then the mud was extremely granular and very lean, and the air dried briquetts had a tensile strength of only 5 pounds. The air shrinkage was 5 per cent. At 2250° F. the total shrinkage was 14 per cent., the bricklets

very porous, of a white color with a mere tinge of yellow. At 2400° F. the total shrinkage was 15 per cent.

In the Deville furnace at cone 27, the clay still remained entirely unaffected, but the color was grayish, and the total shrinkage up to this point amounted to 26 per cent.

The composition of the clay is:

Analysis of Fire Clay, Rock Run, Cherokee Co., No. 4.

Silica	17.70
Alumina	59.46
Ferric oxide	.36
Ignition	22.06
	99.58
Total fluxes	.36

No. 5. This is a soft whitish, easy slaking clay, but a very porous one which absorbs 40 per cent. of water in working it up, and even then gave a very lean mass, whose tensile strength, when made into briquettes and air dried, was only 5 pounds per square inch. The air shrinkage is 4 per cent, and at about 2250° F. the total shrinkage was 17 per cent., but the bricklets, whose color was yellow, were still very porous and could be scratched by a knife without much difficulty; at 2400° F., the shrinkage showed a total of 22 per cent. and incipient fusion began; at 2500° F., the total shrinkage was 23 per cent., the brick was still porous and faintly yellowish white.

In the Deville furnace at cone 30, the clay had burned dense, was incipiently fused, but otherwise unaffected, its color was a grayish white and the total shrinkage amounted to 34 per cent., which is really not surprising when we consider the high amount of combined water that the clay shows, for it is evidently a low grade bauxite like the preceding one.

The composition is:

Analysis of Fire Clay, Rock Run, Cherokee Co., No. 5.

Silica	31.20
Alumina	44.28
Ferric oxide	1.45
Lime	1.00
Magnesia	.20
Ignition	22.60
	100.73
Total fluxes	2.65

This clay is evidently a mixture of clay and bauxite, as can be seen from the high shrinkage and large percentage of combined water.

No. 6. The color of this clay is yellow, and it is fine grained but not hard, and shows numerous slickenside surfaces. In slaking it breaks up easily but slakes completely to powder only after long immersion in water. The clay is very lean, and requires as much water as the preceding to mix it up; the tensile strength is also very low being under 5 pounds. The air shrinkage is 2 per cent., the total shrinkage at 2200° F. is 8 per cent.; at 2250° F. it is 12 per cent.; at 2400° F. it is 13 per cent; at 3500° F. it is 15 per cent.; at 2600° F. it is 20 per cent., and the bricklet was still very absorbent.

In the Deville furnace at cone 27, the clay had burned dense, but still preserved its form with sharp edges and showed a total shrinkage up to this point of 35 per cent.

The composition of the clay is as follows:

Analysis of Fire Clay, Rock Run, Cherokee Co., No. 6.

Silica	34.60
Alumina	45.80
Ferric oxide	.52
Ignition	20.00
	100.92
Total fluxes	.52

REFACTORY BAUXITES.

ROCK RUN, CHEROKEE COUNTY.

In addition to these bauxitic clays, six samples of bauxite were also tested chiefly to determine their refractoriness and their shrinkage in burning, the method adopted with most of them being to grind up the specimen, so that it would pass through either a 20 or a 30 mesh sieve, the particles which did not pass through being also retained. Several mixtures of the coarse and fine material were made. The mass produced in every instance by mixing it with water was extremely low in its plasticity, and lacked greatly in tensile strength, the latter in every instance being not more than 2 or 3 pounds per square inch.

In many cases, the bauxite showed so little tenacity and was so little affected by the heat that bricks which had been burned at a temperature of 2600° F. were easily rubbed apart with the fingers. Another point to be noticed is the enormous shrinkage which all of the specimens exhibited, the air shrinkage, however, being very low.

No. 1. This was powdered and passed through a 30-mesh sieve, and on working up gave a very lean mass, which required 24 per cent. of water. The air shrinkage was 3 per cent. and at 2400° F. the total shrinkage was 11 per cent, while the bricklet was very porous and white. At 2500° F. the bricklet had not shrunk any more but the color had become reddish.

In the Deville furnace at cone 30, the bauxite was totally unaffected although it had become somewhat dense, and showed a shrinkage of 23 per cent. The composition was:

Analysis of Bauxite, Rock Run, Cherokee Co., No. 1.

Silica	8.80
Alumina	61.64
Ferric oxide	1.10
Lime	trace
Magnesia	trace
Ignition	29.97
	100.51

No. 2. Two mixtures were made of this, viz: *a.* which was 50 per cent. of grains between 15 and 20-mesh, and 50 per cent. smaller than 20-mesh. The bricklet made from this showed a total shrinkage of 12 per cent. at 2400° F., while at 2600° F., the shrinkage was 14 per cent. and the bricklet was so friable that it could be easily rubbed apart.

b. The bauxite was ground and passed through a 30-mesh sieve. In this condition it took 25 per cent. of water to mix it up, and made a very lean paste. The shrinkage of the bricklets made from this was about 10 per cent at 2250° F., they were very porous, soft, and of a slight yellowish tint; at about 2400° F. the total shrinkage was 15 per cent. and at 2600° F. amounted to 17 per cent., but the bricklet was still scratched by a knife without much difficulty. In the Deville furnace the bauxite was still uneffected at cone 30, but showed a total shrinkage of 27 per cent.

Its composition is:

Analysis of Bauxite, Rock Run, Cherokee Co., No. 2.

Silica	18.30
Alumina	54.39
Ferric oxide	1.36
Ignition	27.60
	101.65

72. (No. 3.) Ground to pass through a 20-mesh sieve, it gave a very lean mass on the additcn of 25 per cent. of water.

The air shrinkage was 2 per cent.

At 2400° F. the brick was very loose and crumbly.

At 2500° F. shrinkage 11 per cent.

At 2600° F. shrinkage 18 per cent.

At 3150° F. shrinkage 22 per cent. Totally unaffected.

Analysis of Bauxite, Rock Run, Cherokee Co., No. 3.

Silica	3.30
Alumina	69.06
Ferric oxide	.20
Lime	....
Water	28.10
	100.66

48. (No. 4.) Three mixtures were made up as follows:

a. 33 per cent. smaller than 20-mesh.
67 per cent. 10-20 mesh.

b. Under 30 mesh.

c. Under 20-mesh.

All three gave lean mixtures.

a. Took 23 per cent. water to work it up.

b. Took 20 per cent. water to work it up.

c. Took 24 per cent. water to work it up.

The air shrinkage was *b*. 2 per cent., *c*. 1 per cent.

At 2400° F. *b* showed 10 per cent. shrinkage and the particles barely colored.

At 2500°F. *b* had shrunk 11 per cent. and held; *c* 13 per cent. but was very loose.

At 2600° F. *b*. and *c*. had both shrunk 13 per cent. but could still be scratched by the knife.

At 3000° F. the bauxite was unaffected, and showed a total shrinkage of 17 per cent.

Analysis of Bauxite, Rock Run, Cherokee Co., No. 4.

Silica	3.30
Alumina	66.70
Ferric oxide	.10
Water	31.30
	101.40

49. (No. 5.) Mixtures made were:

a. 35 per cent. 10-20 mesh and 65 per cent. under 20 mesh. Required 18 per cent. of water to work up.

b. under 30-mesh. Required 20 per cent. of water.

c. under 20-mesh. Required 25 per cent. of water.

The air shrinkage of all was 1 to 2 per cent.

At 2550° F. the shrinkage was 20 per cent.

The bauxite when heated to cone 30 in the Deville furnace, preserved its form and sharp edges, and showed the faintest trace of incipient fusion. It is therefore highly refractory.

Analysis of Bauxite, Rock Run, Cherokee Co., No. 5.

Silica	.28
Alumina	68.14
Ferric oxide	trace
Water	32.60
	101.02

73. (No. 6.) A whitish, claylike bauxite. This took 46 per cent. of water to work it up and gave a fairly plastic mass, but had very little tensile strength.

At 2400° F. the shrinkage was 10 per cent., bricklet still soft enough to be scratched by the nail.

At 2550° F. shrinkage 27 per cent.

At 2600° F. shrinkage 30 per cent., brick resisted scratching by a knife.

At 3100° F. bauxite dense, gray in color, but form perfectly sharp.

Analysis of Bauxite, Rock Run, Cherokee Co., No. 6.

Silica	9.50
Alumina	61.14
Ferric oxide	trace
Lime	trace
Magnesia	trace
Water	31.20
	101.84

The foregoing tests of these bauxites show a high refractoriness, but also a very high shrinkage which increases apparently with the fineness of grain. It is difficult to draw conclusions from six specimens, however, just what the relations of silica, alumina, water and size of grain are which influence the shrinkage.

All of these bauxities would, of course, have to be first calcined if used for refractory purposes; but they could then be mixed with a small amount of plastic clay to serve as binder and would then make a very refractory article. In my report I shall discuss this point.

(No. 117)

FIRE CLAY.

NEAR VALLEY HEAD, DEKALB COUNTY.

The clay mines of the Montagues are situated about two mile up the railroad from Valley Head, and a few hundred feet to the west of the track. Several grades of clay are obtained from the mines, but they are not restricted in any case to certain layers. The following sample tested is what is known at the mines as the first grade, and its refractory character is not by any means low.

The material is a white sandy clay, rather coarse grained and containing occasional reddish or pinkish stains. There is no mica to be seen in it. It is hard but very porous, and practically does not slake when immersed in water for a long period.

When mixed with 35 per cent. of water it gave a gritty but lean mass, which had an air shrinkage of 4 per cent. In this case it had been ground to pass through a 60-mesh sieve. When ground to pass through a 100 mesh sieve it absorbed the same quantity of water but the plasticity was slightly increased, while the air shrinkage remained about the same.

At 2100° F. the clay burns white; at 2300° F. it is white with a slight tinge of yellow, and at 2350° F. it is the same with the total shrinkage amounting to only 4 per cent. Incipient fusion occurs at 2400° F. and at cone 27 in the Deville furnace the clay vitrified.

The tensile strength is very low, not over 5 or 6 pounds per square inch.

The chemical analysis yielded:

Analysis of Fire Clay, near Valley Head, DeKalb Co. (*No.* 117).

Silica	82.04
Alumina	12.17
Ferric oxide	trace
Lime	trace
Magnesia	.327
Alkalies	.60
Ignition	4.325
	99.462

Total fluxes	9.27
Specific gravity	2.38

The rational composition is:

Clay substance	31.10
Quarts	64.80
Feldspar	3.90
	99.90

(No. 116.)

FIRE CLAY.

NEAR VALLEY HEAD, DEKALB COUNTY.

Occurring in the same quarry is what is known as the second grade of fireclay. This is a fine grained yellowish gray clay containing much fine grit. It slakes quite quickly when thrown in water, and when worked up with 39 per cent. of water gave quite a plastic mass. The air shrinkage of the bricklets amounted to 8 per cent. which is greater than that of the first grade, which was also less plastic. The tensile strength seems to have increased with the plasticity for it amounted to 20 pounds per square inch. When burned to 2350° F. the total shrinkage was 17 per cent. and incipient fusion took place, while vitrification occurred at 2700° F. and at cone 27 in the Deville furnace the clay fused but did not run. It will be thus seen that it is less refractory than the so called first grade, which only vitrified at this latter temperature. Both are to be classed as fireclays however. Up to incipient fusion, the clay remains white, but above that it begins to show a yellowish tint due to the presence of iron oxide in the clay.

The chemical composition of the clay is:

Analysis of Fire Clay, near Valley Head, DeKalb Co. (No. 116).

Silica	79.80
Alumina	11.75
Ferric oxide	1.75
Lime	.75
Magnesia	trace
Alkalies	1.50
Water	4.11
	99.16
Total fluxes	3.50
Specific gravity	2.37

The rational analysis of the clay gave:

Clay substance	31.20
Quartz	58.00
Feldspar	10.80
	100.00

(No. 119).

FIRE CLAY,

FROM NEAR FORT PAYNE, DEKALB COUNTY.

Major F. Y. Anderson has made several openings to the west of the Alabama Great Southern Railroad at several points between Valley Head and Fort Payne.

The clay found in these pits is in appearance not unlike that which is found in the mines of Montague and Griffin to the northward. The different grades are recognized.

The second grade, as it is called, No. 119, is a somewhat soft, gritty, lean clay, of a yellowish color, due to the numerous stains of iron oxide, and when thrown into the water slakes slowly to a powder.

Forty per cent. of water gave a lean mass, and the air shrinkage of the bricklet made from this was 8 per cent. Incipient fusion occurs at 2300° F., the total shrinkage at this point being 14 per cent., and the bricklet is yellowish white. When heated to cone 27 in the Deville furnace the clay showed vitrification. While it is fairly refractory in its nature, at the same time, owing to the yellowish tint developed in burning, it would not, in its natural condition, do for the manufacture of white ware. It is possible, however, that washing might eliminate some of the undesirable impurities.

The chemical composition is as follows:

Analysis of Fire Clay, near Fort Payne, DeKalb Co. (No. 119).

Silica	66.25
Alumina	22.90
Ferric oxide	1.60
Lime	trace
Magnesia	trace
Alkalies	.75
Ignition	9.05
	100.55
Total fluxes	2.35
Specific gravity	2.28

The rational analysis yielded:

Clay substance	40.70
Quartz	47.90
Feldspar	11.20
	99.80

(No. 112).

FIRE CLAY,

FROM BIBBVILLE, BIBB COUNTY.

This is one of the clays used by the fire brick works at Bessemer, near Birmingham. For use it is mixed with several other clays.

The material itself, however, is a very sandy clay, with much coarse grit and appreciable quantity of mica. It is also abundantly stained with limonite in places. When thrown into water it slakes fairly fast and falls to powder. It is quite a plastic clay, but in working it up into a plastic mass it took only 22.6 per cent. of water.

The air shrinkage amounts to 6½ per cent. At about 2200° F. the clay burns creamy white, and shows a total linear shrinkage of 9 per cent. While at about 2300° F. incipient fusion is reached, with the shrinkage the same, and the color buff. Vitrification was not attained until the clay was heated to cone 27 in the Devilie furnace, and even at this temperature the clay cone remained still perfectly sharp.

The tensile strength is moderate, ranging from 75 to 110 pounds per square inch, with an average of 102 pounds per square inch.

The analysis of this fire clay is:

Analysis of Fire Clay, Bibbville, Bibb Co. (*No.* 112).

Silica	74.25
Alumina	17.25
Ferric oxide	1.19
Lime	.40
Magnesia	tr.
Alkalies	.52
Ignition	6.30
	99.39
Total fluxes	2.11
Specific gravity	2.44

(No. 111).

FIRE CLAY,

ELGIN PROPERTY, NEAR WOODSTOCK, BIBB COUNTY.

A sandy, micaceous clay, of yellowish color, which breaks up slowly, but completely, when immersed in water. This needed 23 per cent. of water to work it up, and gave a moderately plastic mass. The air shrinkage amounted to 7 per cent. In burning the bricklets incipient fusion occurred at 2150° F., with a total shrinkage of 14 per cent., and the color of the clay light buff. At about 2300° F. the shrinkage was 16 per cent., and the color yellow. Vitrification took place at 2350° F., and at this point the shrinkage had incresaed to 18 per cent., while the color had changed to grayish. Fusion took place at 2900° F.

The tensile strength is moderate, and varied from 100 to 110 pounds per square inch.

The ultimate composition is:

Analysis of Fire Clay, Woodstock, Bibb Co. (No. 111).

Silica	65.82
Alumina	24.58
Ferric oxide	1.25
Lime	——
Magnesia	tr.
Alkalies	.60
Ignition	8.165
	100.415
Total fluxes	1.85
Specific gravity	2.40

The rational analysis gave:

Clay substance	62.90
Feldspar Quartz	37.00
	99.90

(No. B).

FIRE CLAY,

AUXFORD'S, NEAR HULL'S STATION, TUSCALOOSA CO.

This is a sandy micaceous gray clay, with a slightly reddish tinge, which crumbles to pieces very quickly when immersed in water. When worked up it gives quite a plastic mass, and requires 33 per cent. of water to accomplish it.

The air shrinkage is from 9 to 10 per cent., and at 2000° F. the total shrinkage was only 12 per cent. At this latter temperature the bricklet was hard, grayish red in color, but still somewhat absorbent, while at about 2200° F. vitrification occurred, with a total shrinkage of 14 per cent. The viscosity occurred at

2500° F. The average tensile strength of the bricklet was 155 pounds per square inch, with a minimum of 140 pounds and a maximum of 168 pounds, which is very good.

The composition of the clay is as follows:

Analysis of Fire Clay, Hull's Station, Tuscaloosa Co. (No. B.)

Silica	61.25
Alumina	25.60
Ferric oxide	2.10
Lime	.25
Magnesia	.82
Alkalies	1.35
Ignition	8.10
	99.47
Total fluxes	4.52

(No. 118).

FIRE CLAY,

J. C. BEAN, TUSCALOOSA COUNTY.

It is a fine grained clay, with very little grit, and of homogeneous structure. When immersed in water it slakes with extreme slowness. The addition of 36 per cent. of water to the clay gives a very plastic mass and the bricklets made from this had an air shrinkage of 12 per cent.

When burned to 2200° F. the total shrinkage amounted to 18 per cent., the bricklet was grayish red in color, and very dense, incipient fusion having occurred. When heated to cone 27 in the Deville furnace it only vitrified.

The burning dense of this clay at such a temperature, and the great difference in temperature between the points of incipient sintering and vitrification are worthy of notice, and show it to possess character closely resembling those of many glass pot clays.

The composition of this clay is as follows:

Analysis of Fire Clay, Tuscaloosa Co. (No. 118).

Silica	58.13
Alumina	24.68
Ferric oxide	3.85
Lime	.15
Magnesia	.32
Alkalies	1.78
Ignition	11.78
	100.51
Total fluxes	5.92

The rational composition is:

Clay substance	60.85
Quartz	23.35
Feldspar	15.80
	100.00

Glass pot clays vary in chemical composition, and it is really the physical behavior of the material which it is of importance to know. At the same time the analyses of several other glass pot clays are given below for comparison.

Analysis of Glass Pot Clays

No. 1.

Silica	64.89
Alumina	24.08
Ferric oxide	.29
Lime	.41
Magnesia	.19
Potash	.87
Soda	.16
Ignition	9.29

No. 2.

Silica	55.61
Alumina	27.36
Ferric oxide	2.73
Lime	.87
Magnesia	.67
Alkalies	.71
Titanic oxide	1.28
Sulphuric acid*	.51
Moisture	2.36
Ignition	11.13
*Sulphur	.25

No 1 is from Layton Station, Pa. (1897 Report Pennsylvania State College, p. 90. T. C. Hopkins).

No. 2, St. Louis, Mo., Washed pot clay (Missouri Geological Survey Report, Vol. XI, p. 568.)

(No. 1).

FIRE CLAY,

PEARCE'S MILLS, MARION COUNTY.

This clay forms a bed from four to six feet thick in the ravine to the east of the mill. It is a hard rock-like material, and when mined has more the appearance of a white argillaceous sandstone than a clay. It is very hard, and when thrown into water practically does not slake at all, but it is very porous. When ground to 30 mesh and mixed with water it is very lean, but grinding it to 80 mesh increases the plasticity. In this latter condition it required 37 per cent. of water to work it up. The air shrinkage was 4 per cent., whereas when burned to 2100° F. it was 5 per cent., and at 2200° F. the total shrinkage was 7½ per cent., the color of the bricklet being still white like the original clay, but the porosity great. At about 2300° F. the bricklet developed a slightly grayish tint, and at 2400° the color was the same, but the total shrinkage 10 per cent Incipient fusion did not occur until heated to cone 27 in the Deville furnace. This is a very refractory clay, and one that has a comparatively low shrinkage, due to the large amount of silica in its composition.

Vitrification occurs at cone 30 and viscosity at cone 33 in the Deville furnace.

The composition of this clay is:

Analysis of Fire Clay, Pearce's Mill, Marion Co. (*No.* 1).

Silica	52.95
Alumina	35.10
Ferric oxide	.80
Lime	tr.
Magnesia	tr.
Alkalies	.93
Ignition	11.40
	101.18
Total fluxes	1.73

No. 2).

FIRE CLAY,

PEARCE'S MILLS, MARION COUNTY.

This sample is from a second opening which closely adjoins Pearce's Store, and like the other occurrence in this vicinity, it is very gritty, being even more so than the first, and while the material is very porous, at the same time it slakes very slowly, falling finally to a powdery mass. The fracture of the dry material is hard and angular, the air shrinkage is very low, amounting to only 2 per cent., in the case of sample which had passed through a 30-mesh sieve.

At 2350° F. the shrinkage is only 6 per cent., and the bricklet was creamy white in color, but still very absorbent. In the Deville furnace incipient fusion occurs at cone 27, vitrification at cone 32 and viscosity at cone 34.

The tensile strength is very low, ranging from 5 to 10 pounds.

The very refractory character of this clay is evident, but its leanness would no doubt necessitate its being mixed with a more plastic clay before it could be used.

(No. 57 S.)

FIRE CLAY,

J. W. WILLIAMS, PEGRAM, COLBERT COUNTY.

A black gritty clay, which slakes easily, considerable organic matter present, but no pyrite or mica noticeable.

It required 28.6 per cent. of water to make a workable mass, which, to the feel, was lean and gritty. Bricklets made of this shrank 10 per cent. in drying and 3 per cent. in burning, giving a total shrinkage of 13 per cent.

The average tensile strength of the air-dried briquettes was 46 pounds per square inch.

Incipient fusion occurs at 2150° F., vitrification at 2350° F., and viscosity at 2500° F.

The clay burns to a white body, slightly tinged with yellow.

The following is its chemical composition:

Analysis of Fire Clay, J. W. Williams, Pegram, Colbert Co. (*No. 57, S.*)

Moisture......	1.70	
Silica (total)...	80.55,	free sand 70.10
Alumina...	10.50	
Ferric oxide......	1.53	
Lime....	.34	
Magnesia......	traces	
Water and organic matter	5.85	
	100.47	
Total fluxes......	1.87	

(No. C. S.)

FLINT CLAY,

CHOCTAW COUNTY.

A hard, fine grained, siliceous clay, resembling flint clay in appearance, but containing more silica than such material usually contains. It presents a smooth surface, with conchoidal fracture, and in water practically does not slake at all.[*]

When ground to pass through a 30-mesh sieve it required 15 per cent. of water to make a workable paste and was very lean and granular. The tensile strength was, on the average, 5 pounds per square inch.

The shrinkage in drying was 2 per cent., and at 2300° F. 6 per cent. Incipient fusion occurs at 2300° F., vitrification at 2500° F. and viscosity at 2650° F.

On account of its refractory qualities and low shrinkage, this flinty clay is admirably adapted for admixture with plastic fire clays to serve as grog and prevent undesirable shrinkage. The following two analyses, No. 1, by W. B. Philips, and No. 2, by H. Ries, give the composition of this material:

Analysis of Fire Clay, Choctaw Co. (No. C. S.)

	(1)	(2)
Silica (total)	86.30	85.70
Alumina	5.12	6.15
Ferric oxide	1.60	1.80
Lime	.46	tr.
Water	6.60	7.00
	100.08	100.65
Total fluxes	2.06	1.80
Specify gravity		1.70

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[*] This is a Radiolarion clay, abundant in the Buhrstone division of the Tertiary formation in many localities in Choctaw, Washington, Clarke, Monroe and Conecuh counties. E. A. S.

POTTERY OR STONEWARE CLAYS.

Many clays which are too impure to be used as fire clays are often admirably adapted for pottery purposes. In fact stone ware clays are often somewhat intermediate in their nature between fire clays and pipe clays, that is to say they are too impure for the one purpose and too good for the other.

In the manufacture of stoneware, it is highly essential that the clay should burn to a dense impervious body without requiring too high a temperature to accomplish this, and furthermore if the ware is to be unglazed or is to be coated with a transparent glaze it is important that the clay should burn to a good uniform color. In order to obtain the desired result it is not uncommonly the rule to use a mixture of two or more clays for this purpose.

A stoneware clay should be smooth, and free from coarse grit, otherwise it may be necessary to wash the material, and thus increase the cost of manufacture. The clay, in addition, should be highly plastic in order to permit its being easily moulded without cracking, and the tensile strength should be not less than 150 pounds per square inch. As the ware is to be burned to a vitrified body, it is also desirable that there should be a difference of 150° to 250° F. between the point of vitrification and viscosity. (Earthenware clays are not vitrified.) Excessive plasitcity is undesirable as it necessitates very slow drying and burning of the ware and consequently increases the cost of manufacture; while on the other hand low shrinkage diminishes the loss from cracking or warping.

Iron is a desirable ingredient not only as it tends to give the body a good red color, but in addition serves as a flux. Lime if present as a silicate may form a desirable flux, but carbonate of lime especially if in greater quantities than two or three per cent. is objectionable, and sulphate of lime is likewise not desired as owing to its disassociation at high temperatures blisters may be formed.

A clay vitrifying at a low temperature is more desirable as it requires fuel to burn it.

The pottery clays reported on are all from the Tuscaloosa formation of the Lower Cretaceous except No. 204 from Blount county, and No. 192 from near Rock Run, both of which come from the Paleozoie limestone formations.

(No. 204.)

STONEWARE CLAY

FROM F. S. WHITE, BLOUNT CO.

A very fine grained sedimentary clay of grayish white color with occasional spots of yellow.

It slakes easily when thrown into water and works up to a very plastic mass with 28 per cent. of water. The bricklets made from this had an air shrinkage of 5 per cent.

Then burned at 2200° F. it is nearly dense, cream gray in color and showed a total shrinkage of 17 per cent.

At 2350° F. was vitrified and showed very light gray color and a total shrinkage of 20 per cent.

It fused at the time at cone 27 in the Deville furnace.

The tensile strength of the air dried briquettes was low, ranging from 45 pounds per square inch to 55 pounds per square inch.

The analysis of the clay yielded:

Analysis of Stoneware Clay, Blount Co. (No. 204).

Silica	61.50
Alumina	26.20
Ferric oxide	2.10
Lime	0.50
Magnesia	0.43
Alkalies	0.70
Ignition	7.29
	98.72
Total fluxes	3.73

While this clay is not highly refractory, at the same time it has about the right refractoriness to be used in the manufacture of stoneware, and owing to the dense body to which it burns, is exeellently adapted probably to mix with more opened grained clays, which require a good binding material.

(No. 192.)

POTTERY CLAY

FROM C. C. DAVENPORT, ROCK RUN, CHEROKEE CO.

A green clay, of extreme fineness of grain, great density and breaking with a conschiodal fracture. In water it slackens rapidly to a flocculent mass.

It took 30 per cent of water to work it up and it yielded a lean and somewhat granular mass, which had an air skrinkage of 9 per cent.

The bricklets made from this clay burn to a greenish brown color, and vitrify easily at about 2000° F.

At about 1800° F. incipient fusion occurs, with total shrinkage of 18 per cent., and color brown. The clay fuses to a glassy mass at about 2150° F.

The average tensile strength of the air dried briquettes was 62 pounds per square inch, with a maximum of 70 pounds.

The analysis of the clay shows as follows:

Analysis of Pottery Clay, Rock Run, Cherokee Co. (No. 192).

Silica	57.00%
Alumina	17.80
Ferric oxide	5.60
Lime	2.10
Magnesia	1.20
Alkalies	6.00
Ignition	9.45
	99.15
Total	14.90

The high percentage of fluxes accounts for its easy fusibility, and the best use for this material would perhaps be as a natural glaze. It is exceedingly fine grained. When a slip is made of it and No. 205 (clay from near Kymulga) dipped into it, at cone 3-4 it yielded a transparent glaze.

CHALK BLUFF, ELMORE COUNTY.

At this locality there is a high bluff of clay and sand. The section involves approximately :

Section at Chalk Bluff, Elmore Co.

Sand	6 feet
Yellow clay	4 feet
Dark sandy clay	12 feet
Plastic clay	10 feet

Both the dark sandy, and lower plastic clay were tested and yielded very promising results. The lower bed yields a stoneware clay, and the upper a brick clay. (See Nos. 101 and 122.)

(No. 101.)

STONEWARE CLAY.

CHALK BLUFF, ELMORE CO.

This is a reddish gray fine grained clay, containing much fine mica and also an abundance of organic matter. In water it slakes very slowly. The addition of 38 per cent. of water to the air dried clay gives a fairly elastic mass, and bricklets made from this have an air shrinkage of 6 per cent. At 2100° F. the total shrinkage is 11 per cent., and the color of the burned clay is somewhat reddish. Incipient fusion occurs at this temperature, while vitrification takes place at 2200° F. with a total shrinkage of 13 per cent., the color of the clay when burned to this point being a dull red. Viscosity took place at 2600°, so that the clay is not to be classed as a fire clay, it would probably work however for vitrified ware. The tensile strength is exceedingly high, and runs from 300 to 384 pounds per square inch, and while there is considerable variation, at the same time even the lower figure is very great.

The chemical composition is:

Analysis of Stoneware Clay, Chalk Bluff, Elmore Co. (No. 101).

Silica	60.38
Alumina	20.21
Ferric oxide	6.16
Lime	.09
Magnesia	.720
Alkalies	1.80
Ignition	10.21
	99.570
Total fluxes	8.77

(Nos. 88 and 89.)

POTTERY CLAY.

McLEAN'S, EDGEWOOD, ELMORE CO.

Considerable clay is dug for pottery on the land of Mr. McLean, 4 miles from Prattville, along the line of the C. M. R. R. This clay occurs in large pockets surrounded by sand, it is chiefly of two kinds, i. e., a smooth plastic clay and a sandy one.

The former (No. 88) is very tough, and quite plastic.

In water it slakes in angular fragments, and when worked, requires 32 per cent. of water to develop its plasticity. The clay is rather fine grained, but with a conchidal fracture, and shows iron stains on its joint surfaces.

The tensile strength does not appear in this case to stand in direct relation to the plasticity, for the maximum is only 56 pounds per square inch, and the average 49 pounds.

The clay burns to a buff color, and a dense body, and is quite refractory.

The total shrinkage at 2350° F. is 18 per cent. At 2700 it is 18.05 per cent.

In the Deville furnace, at cone 30, the clay vitrified and showed no evidence of becoming viscous.

The second or sandy clay (No. 89) slakes very quickly. It gives a moderately plastic, but though not so tough a mass as the preceding. The tensile strength is however higher, being 74 pounds on the average, and 92 at the maximum.

The air shrinkage is 8.75 per cent; at 2200° F. the total shrinkage was 11 per cent.; at 2350° the total shrinkage was 12 per cent.

The clay fuses at cone 30 in the Deville furnace.

Associated with these stoneware clays is a bed of ochre which fuses easily to a brownish glass. Its composition is:

Analysis of Ochre, Edgewood, Elmore Co.

Silica	51.14
Alumina	30.13
Ferric oxide	8.35
Lime	tr.
Magnesia	tr.
Alkalies	tr.
Ignition	10.15
	99.77

(No. P. S.)

POTTERY CLAY (BLUISH.)

FROM McLEAN POTTERY, ELMORE CO.

A compact bluish clay which slakes rather quickly in water. It shows little grit to the taste. It required 20 per cent. of water to make a workable mass, which to the feel was smooth and plastic. This mud shrunk 6 per cent. in drying and an additional 6 per cent. in burning, giving a total shrinkage of 12 per cent. The average tensile strength of the air dried briquettes was 55 pounds per square inch with a maximum of 66 pounds. Incipient fusion occurred at 1950° F., vitrification at 2150° F. and viscosity at 2400° F.

The clay burns to a dense, smooth, bluish white body, and should make a good stoneware clay. In burning it had to be heated slowly.

The analysis of it is as follows:

Analysis of Pottery Clay, McLean's, Edgewood, Elmore Co. (No. P. S.)

Silica (total)	62.60
Alumina	26.98
Water	8.60
Ferric oxide	.72
Lime	.40
Magnesia	.36
Alkalies	.65
Moisture	.70
	101.01
Free silica	30.10
Total fluxes	2.13
Sepcifiy gravity	2.37

STONEWARE CLAY

FROM NEAR COOSADA, ELMORE CO.

This is a moderately fine grained but somewhat gritty clay, which however is quite plastic, requiring 26.25 per cent. of water to develop its plasticity.

The tensile strength was on the average 154 pounds, with a maximum of 170 pounds.

The air shrinkage amounted to 8.1 per cent.; at about 2200° F. the total shrinkage was 14 per cent., the clay at this temperature having burned nearly dense, and the brick being a brown gray color; at about 2300° F. the total shrinkage was 15 per cent., the brick was very hard, homogeneous, dense, and still of a brownish gray color though somewhat darker; at 2500° F. the brick was thoroughly vitrified, and showed a slight swelling, the shrinkage at this temperature being only 13.5 per cent. and the color remained unchanged except that it was slightly darker in shade. A test made of this clay in the Deville furnace showed that at cone 26 it had become viscous.

The composition of the clay is as follows:

Analysis of Stoneware Clay, Coosada, Elmore Co.

Silica	66.61
Alumina	21.04
Ferric oxide	2.88
Lime	.40
Magnesia	.58
Alkalies	.70
Water	7.00
	99.21
Total fluxes	4.46

(No. 1 S.)

POTTERY CLAY.

H. H. CRIBBS, TUSCALOOSA,

This is a whitish, fine grained clay with small amounts of grit, which slakes easily to small irregular grains and scales; it required 25 per cent. of water to mix it and gave a moderately plastic mass whose air shrinkage was 6 per cent. and fire shrinkage 4 per cent., giving a total shrinkage of 10 per cent.; briquettes made of this paste had, when air dried, a tensile strength of 68 pounds per square inch and a maximum tensile strength of 78 pounds per square inch.

Incipient fusion occurs at 2000° F., vitrification at 2200° F. and viscosity at 2400° F.

The clay burns to a dense yellowish body; the composition of it is as follows:

Analysis of Pottery Clay, H. H. Cribbs, Tuscaloosa (No. 1, S.)

Total silica	65.35
Alumina	21.30
Water	7.35
Ferric oxide	2.72
Lime	.60
Magnesia	.86
Alkalies	tr.
Moisture	1.44
	99.62
Free silica (sand)	39.25
Total fluxes	4.18
Specific gravity	2.34

Another analysis of this white clay from the Cribbs bed was made by Dr. Wm. B. Phillips and is as follows.

Analysis of White Plastic Clay, Cribbs Place, Tuscaloosa, Ala.

Silica	62.25
Alumina	27.90
Lime	2.36
Ferric oxide	0.10
Loss at red heat	10.00
	102.61
Total fluxes	2.46

If coarse grained this clay would probably work for a low grade of fire brick, as its fusibility would probably be less. It would probably work for potters clay, although it would no doubt be desirable to add a clay possessing greater plasticity and tensile strength to it.

The comparative purposes there are given herewith the tests of two Missouri clays quoted in Vol. XI of Missouri Geological Survey. The one has a much higher tensile strength however:

Analyses of Missouri Clays.

	1.	2.
Silica	65.32	66.26
Alumina	22.68	20.32
Water	7.42	7.80
Ferric oxide	1.81	2.30
Lime	.25	.63
Magnesia	.67	.48
Alkalies	1.72	2.04
Total fluxes	4.45	5.45
Incip. fusion	2000°	2000°F
Vitrification	2200°	2200°F
Viscosity	2400°	2400°F
Average tensile str., lbs. per sq. in.	87	122
Maximum tensile strength	98	135

No. 1 is from Waltman's, Barton Co., used for stoneware.
No. 2 is from Lanigan shaft, Moberly, Randolph Co.

In composition it also resembles somewhat two clays from Ohio.*

Analysis of Ohio Clays.

	1.	2.
Combined silica	25.40	27.68
Free silica	40.81	36.58
Alumina	21.13	22.95
Water	6.29	6.74
Ferric oxide	1.28	1.28
Lime	.51	.45
Magnesia	.18	.37
Alkalies	1.80	1.96
Moisture	1.65	2.05
Total fluxes	4.77	5.86

No. 1. Cooking ware clay, Laresville, Muskingum Co.
No. 2. Stoneware clay, Akron, Summit Co.

In all of these analyses it will be noticed that the percentage of alkalies is higher, but the total fluxes are nearly the same, except in the last one.

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*O. Geol. Surv. VII, 1893.

In the case of the Ohio samples no physical tests have been made.

(No. 115.)

STONEWARE CLAY.

J. C. BEAN, TUSCALOOSA CO.

This is from the property of J. C. Bean, near Tuscalooso, in S. 31, T. 20, R. 11. The bed of clay is 6 feet thick and overlain by 4 feet of white sand.

It is a rather fine grained dense clay, which slakes very slowly. On mixing with 36 per cent. of water, it gave a very plastic mass, whose air shrinkage was 11 per cent., at 2200° F. the clay burned a pinkish brown and showed a total shrinkage of 16 per cent., while at 2250° F. it burned a grayish brown with a total shrinkage of 18 per cent. Incipient fusion occurs at 2100° F., vitrification at 2300° F. and viscosity at cone 27 in the Deville furnace. Owing to the extreme plastice nature of the clay it was very hard to make briquettes which did not show evidence of flaws so that the tensile strength ranged from only 90 to 100 pounds per square inch, which is probably low. Specific gravity 2.40.

(No. 100.)

POTTERY CLAY.

J. C. BEAN, TUCALOOSA CO.

This is a rather fine grained clay, and at the same time a dense one. It contains an appreciable quantity of organic matter which not only increases the plasticity but also necessitates slow drying and burning of the material. The addition of 31.5 per cent. of water to the clay converts it into a very plastic mass, whose shrinkage in air drying amounted to 9 per cent. In burning incipient fusion occurs at 2100° F., at which point the total shrink-

age was 14 per cent. and the bricklet buff in color. At 2200° F. the shrinkage was 16 per cent and the bricklet grayish buff, while vitrification occurred at 2200° F. accompanied by a total shrinkage of 17 per cent. Viscosity took place at 2500° F. The tensile strength was only moderate, being 84 to 85 pounds.

The chemical composition is :

Analysis of Pottery Clay, J. C. Bean, Tuscaloosa Co. (No. 100).

Silica	**60.03**
Alumina	**24.66**
Ferric oxide	**3.69**
Lime	**.13**
Magnesia	**.380**
Alkalies	**tr.**
Ignition	**11.342**
	100.232
Total fluxes	**4.20**

(No. 32 S.)

STONEWARE CLAY.

ROBERTS' MILL, COAL FIRE CREEK, PICKENS CO.

A gray, tough, rather fine grained clay, which in water slakes somewhat slowly to a mixture of grain one-sixteenth to one-thirty-second of an inch in size. Taste gritty. Patches of fine sand and ore scattered through the clay, and associated with them are a few small flakes of white mica.

The clay when ground to 30 mesh and mixed with 21.8 per cent. water gave a workable mass of quite plastic character, which shrunk 4 per cent in drying and 8 per cent in burning, making a total shrinkage of 12 per cent.

Air dried briquettes of the clay had an average tensile strength of 117 pounds per square inch and a maximum strength of 142 pounds.

Incipient fusion occurred at 2000° F.; vitrification at 2200° F. and viscosity at 2400° F.

The clay burned to a stiff buff body, which deepens on hard firing.

The composition is as follows:

Analysis of Stoneware Clay, Roberts' Mill, Pickens Co. (No. 32 S.)

Silica (total)	68.23
Alumina	20.35
Water	6.10
Ferric oxide	3.20
Lime	.34
Magnesia	tr.
Alkalies	.74
Moisture	1.06
	100.02
Free silica (sand)	43.23
Total fluxes	4.28
Specific gravity	2.17

This clay might also serve for stoneware. It burns to a buff color.

In general composition this clay resembles somewhat a stoneware clay used at Zanesville, Ohio*, which is given below. It will be noticed however that while the per centage of total fluxes is very close, the individal ones differ somewhat in amount from those in the Alabama clay.

Analysis of Ohio Clay.

Silica (combined)	25.40
Alumina	21,13
Water	6.29
Ferric oxide	1.28
Lime	.51
Magnesia	.18
Alkalies	1.80
Moisture	1.65
	99.24
Free silica (sand)	40.81
Total fluxes	3.77

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*Ohio Geo. Surv. VII, 193.

(No. 11 S.)

POTTERY CLAY.

CRIBBS PLACE, BEDFORD, LAMAR CO.

A dark-colored, tough blue clay, containing much organic matter. It is very dense, and slakes very slowly. No pyrite and few mica scales were noticeable.

It requires 45 per cent. of water to make a workable mass, which was extrremely plastic and fat. This clay shrunk 12.5 per cent. in drying and an additional 6.5 per ceat. in burning giving a total shrinkage of 19 per cent., which is a large amoumt. The tensile strength of this air dried briquette should be great, but on account of the excessive plasticity it was found hard to mould briquettes which were free from flaws, so that most of them broke at about 100 pounds per square inch. Incipient fusion occurs at 1900° F. Vitrification at 2100° F. and viscosity at 2300° F. The clay burns to a deep red, dense body.

The following is the composition of it.

Analysis of Pottery Clay, Cribbs' Place, Lamar Co. (*No.* 11, *S.*)

Total silica	60.9
Alumina	18.98
Water and organic matter	12.46
Ferric oxide	7.68
Lime	trace
Magnesia	trace
Alkalies	trace
Moisture	.90
	100.92
Free silica (sand)	37.92
Total fluxes	7.68
Specific gravity	2.313

The chief use of this clay would probably be as a bond for leaner clays, in the manufacture of courser grades of pottery, or perhaps sewer-pipe.

In burning it has to be heated very slowly to prevent cracking, and the same holds true of the drying. Its excessive plasticity is in part due to the contained organic matter.

(No. 27 S.)

STONEWARE CLAY.

J. B. GREEN, FERNBANK, LAMAR CO.

A dense, fine grained, compact, tough clay, that falls to pieces extremely slowly in water. No pyrite noticeable. Taste somewhat gritty.

It required 32.6 per cent. of water to make it work up, giving a plastic mass. The shrinkage in drying was 10 per cent., and an additional 7 per cent. in burning, making a total shrinkage of 17 per cent. The tensile strength as determined by pulling apart air dried briquettes of the clay was on the average 152 pounds per square inch with a maximum of 185 pounds per square inch.

Incipient fusion occurs at 1900° F., vitrification at 2100° F., viscosity at 2300° F.

The clay burns to a hard, impervious body, of a deep red color. There is considerable organic matter present in the clay, which adds somewhat to the plasticity.

The analysis of the clay is as follows:

Analysis of Stoneware Clay, Fernbank, Lamar Co. (No. 27 S.)

Silica (total)	69.50
Alumina	13.00
Water and organic matter	6.70
Ferric oxide	6.40
Lime	.25
Magnesia	tr.
Alkalies	tr.
Moisture	3.40
	99.25
Free silica (sand)	43.90
Total impurities	6.65
Specific gravity	2.305

This clay would probably work very well for stoneware.

(No. 71 S.)

POTTERY CLAY.

W. DOTY, FAYETTE CO.

A fine grained, red clay, with little coarse grit, and very few mica scales. Slakes quickly to fine grains. It required 34.3 per cent of water to work it into a mass of good plasticity, the bricklets made from it shrinking 7 per cent. in drying and an additional 6 per cent in burning, giving a total shrinkage of 13 per cent.

The tensile strength of the air dried briquettes, was on the average; 116 pounds per square inch, with a maximum of 155 pounds.

Incipient fusion occurs at 2000° F., vitrication at 2200° F., and viscosity at 2400°.

It burns to a dense hard body of a nice deep red color, which darkens as vitrification is approached.

The composition of the clay is as follows:

Analysis of Pottery Clay, W. Doty, Fayette Co. (No. 71, S.)

Silica (total)	65.58
Alumina	19.23
Water	5.50
Ferric oxide	4.48
Lime	tr.
Magnesia	tr.
Moisture	1.40
	96.19
Free silica (sand)	45.85
Total fluxes	4.48
Specific gravity	2.42

(No. 70 S.)

POTTERY CLAY.

W. DOTY, FAYETTE CO.

A fine grained, rather gritty, reddish clay. In water it slakes quickly to small irregular grains. The addition of 25 per cent of water gave a plastic mass, which shrunk 6.2 per cent. in drying and an additional 5.8 per cent. in burning, giving a total shrinkage of 12 per cent.

Briquettes of the air dried clay had an average tensile strength of 95 pounds per square inch, and a maximum of 151 pounds.

Incipient fusion occurred at 2000° F., and viscosity at 2400° F. The clay burns to a yellowish color at 2000°, but to a red at 2200°. The body of the burned clay is smooth and dense.

The clay analyzed as follows:

Analysis of Pottery Clay, W. Doty, Faette Co. (No. 70 S.)

Silica (total)	67.10
Alumina	19.37
Water	6.08
Ferric oxide	2.88
Lime	tr.
Magnesia	.725
Alkalies	.672
Moisture	1.71
	98.537
Free silica (sand)	43.93
Total fluxes	4.27
Specified gravity	2.416

In compositon this clay resembles some-what a clay used for pottery and sewer pipe, and obtained at Gilkerson Ford, Henry Co., Mo.*

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*Mo. Geol. Survey XI, p. 328.

The composition of this clay is:

Analysis of Clay, Henry Co., Mo.

Silica	67.49
Alumina	21.11
Water	5.95
Ferric oxide	2.45
Lime	.17
Magnesia	.63
Alkalies	2.83
	100.63
Total fluxes	6.08
Specific gravity	2.23

The shrinkage in both drying and burning is six per cent. and the tensile strength in 110 on the average, with a maximum of 127. Incipient fusion begins at 2000° F. complete vitrification at 2300°F., and viscosity at 2400° F.

(No. 68 S.)

POTTERY CLAY (REFRACTORY).

SHIRLEY S MILL, FAYETTE CO.

A fine grained, compact clay, with little coarse grit, but considerable fine sand. Color drab. It slakes very slowly to scaly grains.

Three per cent. of water were required to make a workable paste which was quite plastic. This paste shrunk 10 per cent. in drying and 4 per cent. in burning, giving a total shrinkage of 14 per cent.

The tensile strength of the air dried briquettes showed an average of 106 lbs. per square inch, and a maximum of 123 lbs.

The clay burns to a yellowish white body. Incipient fusion occurs at 2000° F., vitrification at 2200° F., and viscosity at 2400° F., The composition of the clay is as given below:

Analysis of Refractory Pottery Clay, Shirley's Mill, Fayette Co., (No. 68 S.)

Silica (total)	72.20
Alumina	17.42
Water and loss	7.40
Ferric oxide	2.40
Lime	trace
Magnesia	trace
Alkalies	.56
Moisture	.12
	100.10
Free silica (sand)	52.31
Total fluxes	2.96
Specific gravity	2.28

This clay might work for an inferior grade of fire brick, or also for pressed brick of a light color, or even for potter's clay. It resembles rather closely in composition a stoneware clay from Commerce, Scott Co., Missouri,* agreeing closely in every respect except the tensile strength. For sake of comparison the properties of the Commerce clay are given herewith:

Analysis of Clay, Commerce, Mo.

Silica	71.78
Alumina	17.01
Water	8.13
Ferric oxide	2.01
Lime	.34
Magnesia	.43
Alkalies	.78
	100.48
Total fluxes	3.56
Specified gravity	2.03
Incipient fusion	2000° F.
Vitrificaton	2200° F.
Viscosity	2400° F.
Average tensile strength	225 lbs. per sq. inch
Maximum tensile strength	254 lbs. per sq. inch

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*Mo. Geol. Survey, XI, 350.

(No. 23 S.)

STONEWARE CLAY.

HEZEKIAH WIGGINS, FAYETTE CO.

A light gray, hard, compact clay, of moderately silicious character and containing a few scattered mica scales. It slakes very slowly to tough scaly flakes.

In order to make a workable paste the clay required the addition of 34.3 per cent. of water. This paste was markedly plastic. Its shrinkage in drying was 14 per cent. and 8 per cent. in burning, giving a total shrinkage of 22 per cent. The tenacity of the air dried mass was on the agerage 232 lbs. per square inch with a maximum of 300 lbs. per square inch; which is exceeded by comparatively few clays.

Incipient fusion occurs at 1900° F., vitrification at 2100° F., and viscosity at 2300° F. The clay burns to a dense red body, but requires slow drying and heating to avoid cracking.

The composition of this clay is as follows:

Analysis of Stoneware Clay, H. Wiggins, Fayette Co. (No. 23 S.)

Silica (total)	63.27
Alumina	19.68
Water	6.05
Ferric oxide	3.52
Lime	1.30
Magnesia	tr.
Alkalies	1.20
Moisture	3.75
	98.77
Free silica (sand)	39.59
Total fluxes	6.02
Specific gravity	2.32

The clay agrèes in composition in a general way with some of the stoneware clays of Missouri and Ohio, and its shrinkage and tensile strength are similiar to a ston ware clay from Harrisonville, Cass Co., Mo.,* but the latter having nearly 3 per cent. more fluxes fuses at a lower temperature.

(No. 65a. S.)

POTTERY CLAY.

TEN MILES SOUTHEAST OF HAMILTON, MARION CO.

A moderately gritly, medium grained clay with a few mica scales, it required 28.9 per cent. of water to make a workable mass, which is rather lean. The air shrinkage of bricklets made from this was 6.5 per cent. with an additional shrinkage of 5.5 per cent. in burning, making a total shrinkage 12 per cent.

The average tensile strength of air dried briquettes was 58 lbs. per sq. inch with a maximum of 6.5 lbs. per square inch.

Incipient fusion occurs at 1950° F., vitrification at 2150° F., and viscosity at 2350° F.

It burns to a grayish buff color.

The chemical composition is as follows:

Analysis of Pottery Clay, 10 miles southeast of Hamilton, Marion Co. (No. 65a, S.)

Silica (total)	70.00
Alumina	21.31
Water	6.35
Ferric oxide	2.88
Lime	.20
Magnesia	tr.
Alkalies	tr.
Moisture	.50
	101.24
Free silica (sand)	45 80
Total fluxes	3.08
Specific gravity	2.10

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*Mo. Geol. Survey XI, p. 315.

(No. 62 S.)

POTTERY CLAY.

THOMAS ROLLINS, FRANKLIN CO.

A fine-grained tough clay, which slakes very slowly when thrown into water, but splits very easily along thin sandy layers which occur at intervals of about every half inch, a few mica scales are present, the addition of 20 per cent. of water gave a workable and quiet plastic paste.

The shrinkage of bricklets made from this paste was 10 per cent. in drying, and 4 per cent. in burning, or a total of 14 per cent.

The average tensile strength of air dried briquettes was 102 lbs.per square inch, with a maximum of 127 lbs. per square inch.

Incipient fusion occurs at 1900° F., vitrification at 2100° F., and viscosity at 2300° F. The clay burns to a red-gray, but has to be heated very slowly,

The composition of the clay is as follows:

Analysis of Pottery Clay, Thomas Rollins, Franklin Co. (No. 62, S.)

Total silica	67.50
Aumina	19.84
Water	6.15
Ferric oxide	6.15
Lime	.12
Magnesia	.10
Moisture	1.50
Total	100.97
Free silica (sand)	43.46
Total fluxes	5.90
Specific gravity	2.36

(No. 55 S.)

POTTERY CLAY (REFRACTORY.)

J. W. WILLIAMS, PEGRAM, COLBERT CO.

A white clay of fine grain, which slakes easily in water. The addition of 26 per cent. of water gave a lean workable mass which shrunk 5 per cent. in drying, and 10 per cent. in burning, giving a total shrinkage of 15 per cent. The average tensile strength of air dried briquettes per sq. inch is 30 lbs, and the maximum tensile strength per sq. inch is 35 lbs.

Incipient fusion occurs at 2150 F., vitrificataon at 2300 F., and viscosity at 2500 F.; the clay burns to a dense yellowish white body.

Following is the composition of the clay:

Analysis of Pottery Clay J. W. Williams, Pegram, Colbert Co. (No. 55 S.)

Total silica	66.45
Alumina	18.53
Ferric oxide	2.40
Water	8.68
Lime	1.50
Magnesia	1.25
Alkalies	tr.
Moisture	.78
	99.59
Free silica (sand)	44.22
Total fluxes	5.15
Clay base	49.44
Specific gravity	2.39

This clay could probably be purified by washing, it corresponds in general composition to a fire clay from Parker and Russel's Mine* near St. Louis Mo., but the latter on account of its greater coarseness, has a larger refractoriness.

BRICK CLAYS.

The term brick clays is a somewhat elastic one for it may include those used for the manufacture of common brick, front or pressed brick, and paving brick. As the requirements are somewhat different they can be mentioned briefly and apart.

Clays for common brick. For this purpose almost any

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*Missouri Geol. Survey. Vol. XI, p. 570.

clay suffices, in fact so little attention is applied to material used for this purpose, that the product is often soft and porous. Clays for common brick should not be excessively sandy, otherwise the brick will be weak and porous. They should possess sufficient plasticity to mould without cracking, but not be so plastic as to warp, due to excessive shrinkage. Most brick clays burn red. Ferruginous clays can be more safely burned to a hard product than clacareous ones, which burn buff or cream colored.

The methods used for moulding common brick are the *soft mud*, by which the soft plastic mass is forced into the mould; and *the stiff mud*, in which the clay is forced from a die of rectangular cross section and then cut up into bricks. The latter method gives greater capacity, but the bricks unless thoroughly burned will not stand the weather as well. Very plastic clays and very lean ones are adapted to the stiff mud process, the former because they are not tenacious enough, the latter because owing to their pastiness and the structure of the machine a laminated structure is developed in the brick.

Brick clays should have a tensile strength not less than 50 lbs. per square inch. They are not required to stand a high degree of heat, a few common brick kilns attain a temperature of over 1800 or 1900 degrees Fahr.

The more rapidly the clay slakes the easier will it be to temper it.

Clays for front or pressed brick. For this purpose a lighter grade of clay is required, and the material must not only burn to a hard body but also to a uniform color, for on the latter depends much of the beauty of the structure. In no branch of the clay working industry is the range of colors producible from natural clay mixtures more carefully considered than in the manufacture of pressed brick.

Many shades are obtained either by mixing two or more clays, or by adding artificial coloring agents to the raw materials.

Clays for front brick should shrink evenly in burning, and not warp nor crack. Straightness of outline and evenness of size are essential to close fitting when set in the wall.

Many front brick are moulded by the dry-press process, in which the clay is forced into the mould in the form of a dry powder. Such bricks have straight edges and smooth surfaces, but unless burned good and hard they chip easily. At many localities the clay is moulded in soft mud or stiff mud machines, and the brick, while still soft, re-pressed in a second machine whereby the surfaces are smoothed even and the edges straightened. These latter brick do not tend to exhibit the same brittleness along the edges as the dry press brick are apt to.

Front brick sell from $15.00 to $70.00 per 1000, depending on the color and shape.

Clays for paving brick. The nature of these must be such that they can be burned to vitrification. To do this economically and on a large scale the points of vitrification and viscosity should be at least 125° F. apart and preferably 200° F. If they were not it would be impossible to bring a kiln full of bricks to vitrification without running them up to the temperature of viscosity. For this reason calcareous clays are not well adapted to paving brick manufacture.

Paving brick clays should possess moderate or good plasticity so that they can be moulded by the stiff mud process, and while it is desirable that the tensile strength should be 75 pounds or more, at the same time many good pavers are made from mixtures whose tensile strength is not over 50 pounds per square inch.

Shales are used to a large extent for the manufacture of paving brick, partly because many of them contain about the right quantity and kind of fluxing impurities, and also because, owing to the fineness of grain, they vitrify more evenly and thoroughly.

Paving brick are at times made from fireclay, and the results obtained are excellent, but still shale is the favored material.

Except for comparing brick made from the same deposit, the color is absolutely no indication of the quality of a paving brick.

The important properties which a paving brick should show are low absorption (under 2 per cent.) and resistance to abrasion. Crushing strength is of little importance provided it exceeds say 8,000 pounds per square inch.

The brick clays described below come from several geological formations. The Graves' shales, Nos. 107 and 108; the Coaldale shale and the Pearce Mill shale, No. 3, are Carboniferous shales. The Dixie clay and No. 128 and 129 of Mr. Stevens, are from the Poleozoic limestones, while the rest, No. 110 from Shirley's Mill, No. 122 from Chalk Bluff, Elmore Co.; No. 126 of Mr. Stevens, from Woodstock; No. A, from Tusealoosa Co., are from the Tuscaloosa formation of the Sower Cretaceous.

(Nos. 107 and 108.)

BRICK-SHALES.

W. H. GRAVES, BIRMINGHAM, JEFFERSON CO.

Associated with the coal on the property of Mr. W. H. Graves are two beds of shale, viz: a yellow, sandy shale, and a gray one containing much less grit. Both of these were tested physically and the results of these tests are given below. The yellow shale contains a high per centage of ferric oxide and fuses very easily, while the gray shale contains several per cent. less, and is much better adapted to the manufacture of vitrified wares. The composition and physical characters of the two are given side by side for the purposes of comparison.

Light or gray shale, No. 108.

Plasticity, quite good. The shale takes 25 per cent. of water to work it up.

Air shrinkage 2 per cent.

Shrinkage at 2000° F., 9 per cent. Brick good red color not, very porous.

Shrinkage at 2200° F., 12 per cent. Brick reddish brown, and just about vitrified.

Fusion a 2500° F.

Tensile strength—average 105 pounds, minimum 85 pounds per square inch.

Dark or yellow shale, No. 107.

Plasticity moderate; shale gritty, requires 20 per cent. of water to work it up.

Air shrinkage 1½ per cent.

Shrinkage at 2000° F., 5 per cent. Brick good red color. Somewhat porous.

Shrinkage at 2150° F., 6½ per cent, Brick nearly dense, reddish towards brown.

At 2250° F., nearly vitrified.

Fusion at 2500° F.

Tensile strength only 40 pounds to square inch.

Analysis of shales, Birmingham, Jefferson Co. (No. 107 and 108.)

	(108)	(107)
Silica	57.80	61.55
Alumina	25.00	20.25
Ferric oxide	4.00	7.23
Lime	2.10	tr.
Magnesia	80	.986
Ignition	7.50	6.19
Alkalies	1.80	2.25
	99.00	98.466
Total fluxes	8.70	8.45
Specific gravity	2.12	2.23

The gray shale burns to a denser, harder body than the yellow, and does not blister as easily in burning owing to its lower per centage of iron.

PAVING BRICKS SHALE,

COALDALE, ALA.

A yellowish red, soft shale, with considerable grit. No mica or pyrite noticeable.

Ground to 30 mesh and mixed with 22 per cent. of water it gave a lean paste, which shrunk 4 per cent. in drying and 5.5 per cent. in burning, giving a total shrinkage of 9.5 per cent.

The tensile strength of the air dried briquettes was on the average of 25 pounds per square inch with a maximum of 35 pounds.

Incipient fusion occurs at 1900° F., vitrification at 2000° F., and viscosity at 2150° F.

The shale burns to a red body and makes a good red brick. It is also used for paving brick.

(No. 33.)

RED SHALE,

PEARCE'S MILLS, MARION CO.

There is an an extensive outcrop of partially weathered Carboniferous shale along the private road of Mr. Pearce just before reaching the millls. It is a red, rather fine grained material, and contains a small amount of mica. Its soft character renders the mining of it an easy matter. When ground the shale gives a moderately plastic mass whose plasticity could no doubt be increased by weathering. Forty per cent. of water were required to work it up, and the bricklets made from this material had an air shrinkage of 4 per cent. When burned to 2000°

F., the total shrinkage was 8 per cent., and the color of the bricklet was a rich red. At 2100° F., the color of the bricklet was the same, and the shrinkage was 9 per cent., incipient fusion having occurred at this point. Vitrification occurs at 2200° F., and the color is deep red, while viscosity took place at about 2300° F. In drying the clay showed little evidence of containing any appreciable quantity of soluble salts that would tend to form any efflorescence, nor did any show themselves afetr burning.

The comparatively small shrinkage and the rich red color to which the clay burns would make it admirably adapted to the manufacture of pressed brick, but unless it was mixed with a more plastic clay it would hardly work for the production of terra cotta.

The semi-weathered character of the material would also facilitate the preparation of it.

(No. A.)

PAVING BRICK CLAY,

TEN MILE CUT, TUSCALOOSA CO.

The sample of this clay was collected by the writer from what is known as the Ten Mile Cut on the M. & O. R. R., west of Tuscaloosa. It is a somewhat gritty clay, which contains thin seams of sand. The general color of the clay is bluish-gray, but here and there it shows stains of limonite especially on the sandy fractures. When thrown into water it slakes and gives in working a somewhat gritty, but quite plastic mass, which requires 26.00 per cent. of water to work it up.

The air shrinkage of the clay amounted to 8½ per cent. while at 2200° F., it was only 10 per cent., and at 2300° F., 12 per cent., at which point incipient fusion occurred.

Vitrification took place at cone 27 in the Deville furnace and fusion above cone 30.

The tensile strength of the air dried briquettes varied from 126 to 144 pounds per square inch with an average of 140 pounds. The clay burns to a buff color, and is to be classed as a refractory one although it is not highly so. Its location is excellent for cheap working, and easy shipment of the product, and while it has been put under the head of paving brick clays there is no reason why it should not find uses in other directions as well.

The chemical composition of this clay is as follows:

Analysis of Paving Brick Clay, Tuscaloosa Co. (No. A.)

Silica	72.70
Alumina	19.61
Ferric oxide	.934
Alkalies	.80
Ignition	6.50
	100.544
Total fluxes	1.734

PRESSED BRICK CLAY,

DIXIE POTTERY CO., OXFORD, CALHOUN CO.

This is the clay used by the Dixie Tile and Pottery Co. For the manufacturer of buff brick, the clay is quite plastic, and considering this fact it does not seem to require an extraordinary amount of water to work it up. The amount used being only 25.75 per cent. The average tensile strength is 130 pounds per square inch, with a maximum of 144 pounds. In air drying the clay shrunk about 10 per cent; at about 2200° F. incipient fusion began, and up to this point the clay had burned a buff color but then began to burn to a grayish tint; vitrification took place at 2400°, and the total shrinkage to this point was

18 per cent. The clay fused or became viscous at 2600° F. The following is a composition of it:

Analysis of Pressed Brick Clay, Oxford, Calhoun Co.

Silica	71.30
Alumina	17.16
Ferric oxide	1.94
Lime	.60
Magnesia	.43
Alkalies	.95
Ignition	7.60
	99.98
Total fluxes	3.92

This clay should make a good buff colored ware if burned at a comparatively low temperature, but if burned to vitrification the color would of course be much darker as indicated by the test, and owing to the high shrinkage in burning it would be necessary to conduct the latter slowly and with care to prevent cracking of the clay.*

(No. 110.)

PRESSED BRICK CLAY.

SHIRLEY'S MILL, FAYETTE CO.

The clay from this locality is a very fine grained dense one, but at the same time breaks up very easily.

It took 33 per cent. of water to work it up, and the air shrinkage of the bricklets was 6 per cent.

Incipient fusion occurs at 2100° F.

Vitrification took place at 2200° F. and at this point, the bricklet showed a total shrinkage of 16 per cent., and a deep cream color.

In the Deville furnace, at cone 27, the clay became viscous.

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*These bricks are well known in Alabama, and deserve to be even more generally usd than they are. E. A S.

While this clay is not to be looked upon as a refractory one, it would seem that owing to the beautiful color, to which it burns, it would be highly desirable for the manufacture of pressed brick.

The composition of the clay is:

Analysis of Pressed Brick Clay, Shirley's Mill, Fayette Co. (*No. 110.*)

Silica	71.32
Alumina	20.10
Ferric oxide	1.05
Lime	tr.
Magnesia	.316
Alkalies	tr.
Ignition	7.505
	100.291
Total fluxes	1.366
Specific gravity	1.90

(No. 122.)

BRICK CLAY.

CHALK BLUFF, ELMORE CO.

The upper half of the clay bed at this locality is composed of a dark, dense, grayish brown clay which contains a large amount of organic matter, either in a finely divided condition or in the form of leaves. Although not sandy, at the same time it is rather lean when mixed up with water, and owing to the presence of so much organic material absorbed 40 per cent. of water when it was being worked up to a plastic mass. The air shrinkage was however only 6 per cent. At 1900° F. it had reached a total of 14 per cent., but the bricklet was still very absorbent; at 2100° F. incipient fusion had been reached and the total shrinkage was 18.7 per cent., while the color was brownish red; and at about 2200° F. the total shrinkage was 20 per cent. and the color brown, and this color had deepened considerably at 2250° F. with the ap-

appearance of vitrification ,while the maximum shrinkage amounted to 21 per cent. Viscosity was obtained in the Deville furnace at cone 27.

This clay therefore shows an appreciable and safe distance between vitrification and viscosity. The tensile strength is however low, averaging 75 pounds per square inch, with a maximum of 97 pounds per square inch, and a minimum of 68 pounds. Specific gravity, 2.41.

(No. 26 A. Stevens.)

BRICK CLAY.

WOOKSTOCK, BIBB CO.

This is quite a plastic clay, which requires 29 per cent. of water to produce its maximum plasticity. The air shrinkage was 6 per cent., and the average tensile strength was 101 pounds per square inch, with the max - mum of 104 pounds. The fire test gave the following results:

At 2250° F., the shrinkage 10 per cent, clay incipiently fused, color buff.

At 2400° F., shrinkage 11 per cent., color a dark buff.

At 2500° F., clay vitrified, color reddish.

Viscosity occurs at cone 27 in the Deville furnace.

The composition of the clay is:

Analysis of Brick Clay, Woodstock, Bibb Co. (No. 126 A. Stevens.)

Silica	74.20
Alumina	17.25
Ferric oxide	1.22
Lime	.30
Magnesia	.40
Alkalies	tr.
Ignition	7.35
	100.72
Total fluxes	1.92

(No. 129, Stevens.)

BRICK CLAY.

BIRMINGHAM.

This is a very dense hard clay, which required considerable grinding to break it up. The different lots were mixed up, and the one, A, being composed of two-fifths of the clay which was passed through 20 mesh sieve, and thee-fifths of particles greater than 20 mesh.

The second lot, B, was made up entirely of that which had passed through the 20 mesh sieve.

Both lots gave a rather lean mass, but A required 19 per cent. of water and B 16 per cent. to work up. The average tensile strength of A is 12 pounds, and that of B 35 pounds. The air shrinkage of both was 4 per cent.

In burning to 2300° F. the shrinkage of A was 3 per cent, the color of the bricklet a full yellow, and the body very absorbent. At 2400° F. incipient fusion occurred in both cases, and the color of the bricklet was a brownish gray, and the total shrinkage 10 per cent.

At 2500° F. the clay was vitrified, of a dull brownish gray color, and showed a very homogeneous fracture.

Viscosity occurred at 2700° F.

The chemical composition of the clay is:

Analysis of Brick Clay, Birmingham. (No. 129 Stevens.)

Silica	67.30
Alumina	16.10
Ferric oxide	7.77
Lime	tr.
Magnesia	tr.
Alkalies	tr.
Ignition	9.25
Total fluxes	100.42

paste, which to the feel was very slightly plastic and it tasted gritty. In shrinkage in drying was 6 per cent. and 3 per cent. in burning, making a total shrinkage of 9 per cent.

Air dried briquettes of the mud had an average tensile strength of 66 pounds per square inch, and a maximum tensile strength of 68 pounds per square inch.

Incipient fusion occurred at 2000° F.; vitrification at 2160° F. and viscosity at 2300° F.; at 2000° F. it burns to a buff, but on retrifying it becomes red in color.

The composition of the clay is as follows:

Analysis of Clay, H. Palmer, Bexar, Marion Co. (No. 40 S.)

Silica (total)	71.33
Alumina	21,88
Water	5.54
Ferric oxide	.32
Lime	.234
Magnesia	.305
Moisture	1.05
	100.659
Free silica (sand)	46.45
Fluxes	.859
Specific gravity	2.305

(No. 12.)

CLAY FROM H. PALMER,

BEXAR, MARION CO.

A fine grained clay, with sandy laminae and mica scales between the layers. It slakes slowly to fine particles and grains of sand.

The clay required the addition of 31 per cent. of water and gave a moderately plastic mass, that shrank 5 per cent. in drying and 3 per cent. in burning, making a total shrinkage of 8 per cent. The briquettes made from this paste had, when air dried, an average tensile strength of 85 pounds per square inch, with a maximum of 89 pounds per square inch.

Incipient fusion occurs at 1950° F., complete vitrification at 2150° F., and viscosity at 2350° F. The clay burns to a yellowish red body.

Its composition is as follows:

Analysis of Clay, H. Palmer, Bexar, Marion Co. (No. 12)

Total silica	69.93
Alumina	20.15
Water	5.90
Ferric oxide	1.38
Lime	.42
Magnesia	tr.
Alkalies	tr.
Moisture	1.20
	98.98
Total fluxes	1.80
Specific gravity	2.28

(No 41 S.)

MOTTLED CLAY.

BEXAR, MARION CO.

A very open grained, sandy clay, with scattered scales of mica and occasional iron stains. It slakes very quickly to its component mineral grains.

It required 39 per cent. of water to work it up. It is slightly plastic, and shrunk 6 per cent. in drying with an additional 11 per cent. in burning, making a total shrinkage of 17 per cent.

Air dried briquettes of the mud had an average tensile strength of 15 lbs. per square inch, and a maximum of 80 lbs. per square inch.

Incipient fusion occurs of 2000° F., vitrification at 2150° F., aud viscosity at 2300. The clay burns to a red, but not very smooth body.

The clay analyzed as follows:

Analysis of Mottled Clay, Bexar, Marion Co. (No. 41 S.)

Silica (total)	72.40
Alumina	14.86
Water	5.05
Ferric oxide	7.64
Lime	.20
Magnesia	.40
Moisture	.65
	101.20
Free silica (sand)	55.20
Fluxes	8.24
Specific gravity	2.445

(No. 18 S.)

BLUE CLAY.

THIRD CUT NEAR GLEN ALLEN, MARION CO.

A very fine-grained soft clay with little grit, which slakes very readily on being thrown into water.

It required 28 per cent. of water to make a workable mass which was slightly plastic. The shrinkage of this paste in drying was 8.3 per cent., and in burning 7 per cent., giving a total shrinkage of 15.3 per cent. The tensile strength of the air dried briquettes was 56 lbs. per square inch on the average, with a maximum of 65 lbs. per square inch.

Incipient fusion occurs at 1950° F., vitrification at 2150° F., and viscosity at 2350° F.

The clay burns to a light bluff.

The composition on analysis was found to be as follows:

Analysis of Blue Clay, R. R. Cut, near Glen Allen, Marion Co. (No. 18 S.)

Silica (total)	68.10
Alumina	21.89
Water	5.05
Ferric oxide	2.01
Lime	.80
Magnesia	.28
Alkalies	.40
Moisture	.70
	99.230
Free silica (sand)	41.60
Total	4.19
Specific gravity	2.44

The fineness of grain is probably accountable for the low tensile strength and comparatively low temperature of vitrification and fusion. As far as the composition is concerned it is not unlike some of the potters clays used it the United States, but its low tensile strength would probably act against its utility for this purpose, unless mixed with a more plastic clay. For building materials it would no doubt work all right. Being of fine uniform grain permits the production of a very smooth surface on the ware.

(No. X. S.)

CLAY FROM W. J. BECKWITH'S.

COLBERT CO.

A moderately fine-grained, homogeneous, brittle, porous clay, with a semi-couchoidal fracture. In water it slakes slowly to particles mostly under one-sixteenth inch in size.

When mixed with 28 per. cent. of water it gave a lean mass of somewhat gritty feel, which shrunk 5 per cent. in drying and 6 per cent. in burning, or a total shrinkage of 11 per cent. The clay had to be dried and burned slowly to prevent cracking.

Air dried briquettes made of the mud had an average tensile strength of 22 lbs. per square inch, and a maximum strength of 38 lbs.

Incipient fusion occurs at 2050° F., vitrification at 2250° F., and viscosity at 2450° F.

The clay burns to a deep buff body, and requires careful heating to avoid cracking.

An analysis of the material gave the following results:

Analysis of Clay, W. J. Beckwith, Colbert Co. (No. X S.)

Silica (total)	58.20
Alumina	29.86
Water	9.12
Magnesia	tr.
Lime	.20
Ferric oxide	2.22
Alkalies	tr.
Moisture	1.18
	100.78
Free silica	22.59
Total fluxes	2.44
Specific gravity	2.18

THE UTILIZATION OF CLAY FOR PORTLAND CEMENT.

Aside from being used for the manufacture of clay products, there remains the possibility of using some of the Alabama clays for the manufacture of Portland cement. The three essential elements of this material are lime, silica and alumina. The first of these is supplied by limestone, marl or chalk, while the other two are contained in clay.

In the manufacture of Portland cement the two materials are ground and intimantely mixed after which they are burned to vitrification. During the burning certain compounds are formed, especially calcic aluminates and silicates, whose union with water and subesquent crystallization causes the cement to set. The mixture of clay and limestone is manipulated so that in the finished product, the per centage of lime shall be equal to 2.8 times the silica plus 1.1 times the alumina and to maintain this constancy requires that the composition of the materials used must be constantly watched.

While it is possible to get a proper cement mixture from materials showing an appreciable range in composition, at the same time care must be exercised. Highly siliceous clays or limestones are undesirable, the materials used often contain ferric oxide, magnesia or alkalies.

Their affect according to Shewberry is as follows: Ferric oxide combines with lime at a high heat and acts like alumina in promoting combinations of silica and lime. For practical purposes the presence of ferric oxide in a clay need not be considered in calculating the amount of lime required.

Alkalies so far as indicated by the bebavior of soda, are of no value in promoting the combination of silica and lime, and probably play no part in the formation of cement.

Magnesia though possessing marked hydraulic properties when igniled alone, yields no hydraulic products when heated with clay, and probably plays no part in the formation of cement, and it is incapable of replacing lime in cement mixtures.

The following analyses taken from the 1897 Mineral Industry will give an idea of the composition of clays used in portland cement, while following them are several Alabama occurence that could no doubt be used in cement manufacture.

FOREIGN CLAYS.

LOCALITY.	$Si\,O_2$	$Al_2\,O_3$, $Fe_2\,O$		$Ca\,CO_3$	$Ca\,O$	$Mg\,Co_3$	$Mg\,O$	Ign.
Glens Falls, N. Y.	55.27	28.15			5.84		2.25	8.50
Warner's, N. Y.	40.48	20.95		25.80		.99		11.90
Sandusdy, O.	64.70	11.90	9.90		.90		.70	7.90
Bronson, Mich.	62.10	20.09	7.81		.65		.96	12 08
Yankton, S. D.	57.98	18.26	4.57		1.75		1.83	5.16
White Cliff, Ark.	53.30	23.29	9.52		.36		1.49	6.12
" " "	65.12	19.05	7.66		.34		.31	
Medway, Eng.	63.66	16.16	6.74		.81		1.73	
Belgium, Beerse clay	65.50	18.55	6.01		.38		1.18	
Stettin, Germany	54.60	18.20	5.40		2,80		13.16	13.10

ALABAMA CLAYS.

LOCALITY.	Si O_2	Al_2 O_3	Fe_2 O_3	Ca O	Mg O	Alk.	Ign.
H. H. Cribb's, Tuscaloosa	63.35	21.30	2.72	.60	.86	....	7.35
Prattville	62.60	26.98	.72	.40	.36	.65	8.60
Birmingham, Graves' Mine.	57.80	25.00	4.00	2.10	.80	1.80	7.50
W. J. Beckwith, Colbert Co	58.20	29.86	2.24	.20	tr.	tr.	9.12
Pearce's Mill	52.95	35.10	.80	tr.	tr.	.93	11.40
Bedford, Lamar Co.	60.90	18.98	7.68	tr.	tr.	tr.	13.46

It is not necessary to give more than a few, additional cases being given in the preceding pages.

Limestone and marl or chalk is to be found at many localities within the State, so that both the materials used for Portland cement are available.

With the increasing use of this material, and the absence of any factories in the South, it would seem that Alabama offers an excellent field for the establishment and operation of several.

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